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THE ERRORS OF THE ZEUNER DIAGRAM AS APPLIED TO THE STEPHENSON LINK MOTION.*

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I. INTRODUCTION.

THE mathematical elegance of Professor Gustav Zeuner's *Treatise on Valve Gears* is due to the fact that he has shown that the equation representing the distance of a slide valve, controlled by an eccentric or by means of a link, is in all cases with greater or less approximation the polar equation of a circle. Deservedly his work has met with a most gratifying acceptance from all educated engineers, as not only being the most correct, but also the only method which, without the aid of models or templates, enables the practioner to devise and study any desired form of valve gear.

The lack of practical knowledge on the part of most of the students of engineering in the University of Pennsylvania, rendered a working model necessary to the full comprehension of the valve diagram, and the attachment of a drawing board which should turn synchronously with the crank, upon which a pencil attached to the top of the slide valve should mark the curve (approximately a circle) showing its distances from its central position for each position of the crank, naturally suggested itself.

As shown in the drawing (Fig. 1) upon the top of a standard behind the section of the cylinder a pulley of equal size with the crank shaft was connected with the crank shaft by means of a steel saw band running upon thin gutta percha strips glued to the shaft and pulley surfaces. This steel band was kept very taut by means of a stretching pulley about the middle of its length.

Upon the end of the pulley shaft and just back of the valve a drawing board was so attached as to permit a pencil, attached to the valve and kept pressed against the paper stretched upon the drawing board, to trace the curve, showing the distance of the valve from its central position.

So elaborate an apparatus as this would not have been needed, had it not been deemed desirable to avoid all possible causes of obscurity in the students' minds.

Had the drawing board been attached directly to the crank shaft, and a rod having a pencil in the end been attached to the link block, or any point on the valve or valve stem, and carried back to the center of the board, it would have

* The drawings for this article were made by Mr. G. H. Lewis, a graduate of the Department of Dynamical Engineering, and used by him as part of a thesis.
The mathematical treatment is my own. Mr. Lewis' drawings have been somewhat added to, in order to give graphical methods of determining the errors of the diagram. I am indebted to Mr. Lewis for many ingenious and thoughtful suggestions, and much accurate and painstaking work in tracing the diagrams.—W. D. M.

been more serviceable for scientific purposes, as eliminating some of the possible sources of error due to the imperfections of the model.

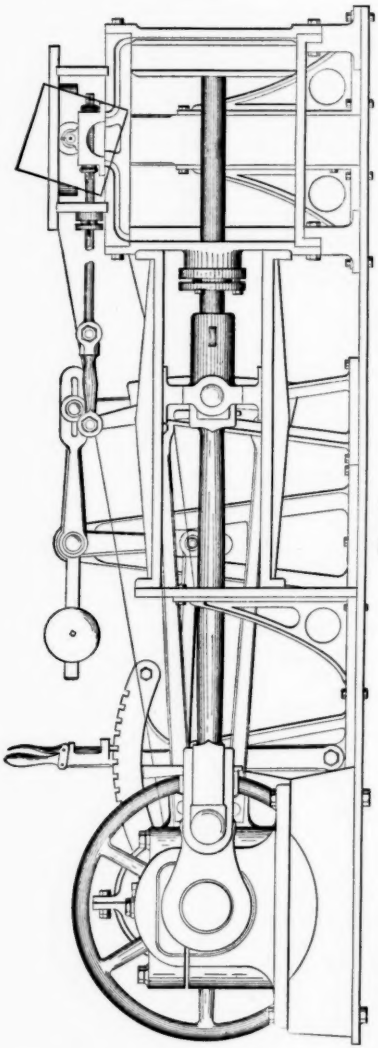

FIG. 1.

This model was constructed of iron, brass and mahogany, and every possible precaution was taken to obtain rigidity and avoid shrinkage; it was constructed full size from the dimensions stated by Zeuner in his Treatise on Valve Gears, page 78.

Eccentricity $=r=2.36$ inches.
Angular advance $=\delta=30°$.
Length of the eccentric rods $=l=55.1$ inches.
Half length of the link $=c=5.9$ inches.
Outside lap $=e=0.94$ inches.
Inside " $=i=0.27$ "

Open eccentric rods and equal angles of advance were taken. The link was so attached to the eccentric rods as to permit the link block to be placed immediately in front of the ends of the eccentric rods; in other words, so that the variable distance u of the link block from the center of the link could at its maximum be made equal to the half length of the link c.

This form of link is shown in Fig. 2 a.

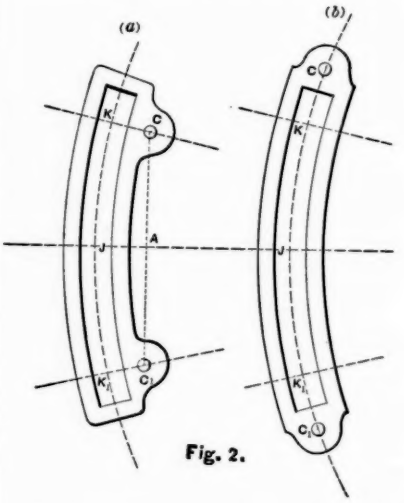

Fig. 2.

The diagrams taken upon this model clearly showed that some greater sources of error existed than the so-called "Missing Quantity" of Zeuner.

Acceptance of authority is a great preventive of advancement of knowledge, and it will be our task to show clearly what points have been overlooked by Professor Zeuner, with, we hope, the result of making even more clearly understood this construction, so simple in its mechanism and so intricate in its action.

II. The Simple Slide Valve. Consideration of the Missing Quantity in the Simple Slide Valve. Setting Valve for Equal Leads Equivalent to Altering the Laps of the Valve.

For the sake of simplicity let us first consider the simple slide valve.

On page 11 of his Treatise on Valve Gears, Zeuner gives for the distance of a simple slide valve from its center of motion ξ

$$\xi = r\sin(w+\delta) + \frac{r^2}{2l}\sin(2\delta+w)\sin w$$

The first term of the second member of this equation is the polar equation of a circle, with the origin in its circumference and its diameter forming an angle equal to δ; with the axis of ordinates OY (see Fig. 3) w is the angle which the crank forms with the axis of abscissas OX. All of this can readily be understood from the explanations given in the book.

It is with the second term of the second member—"the missing quantity"—that we shall have particularly to deal, for Zeuner has considered it as inappreciable in most cases, which is not practically true, for many cases occur in which of necessity the eccentric rods are comparatively short.

Dr. Zeuner fixes the central position of the slide valve by taking the mean of the two positions of the valve when the crank is on its dead points; he does this on the assumption that the valve will be set for equal leads, which is always the proper method.

This central position differs from the true central position by a quantity $= \frac{r^2\cos^2\delta}{2l}$ for the true central point of the valve travel is a mean between the extreme positions of the valve and further away from the crank shaft, a distance equal to the above-stated quantity, therefore at one extreme the valve's distance from Zeuner's center $= r + \frac{r^2\cos^2\delta}{2l}$ and at the other extreme $= r - \frac{r^2\cos^2\delta}{2l}$.

If now we can convert the missing quantity into a function of the theoretical valve distance, from its center for equal leads (Zeuner's center), we can much more conveniently lay down the irregular curve of the valve circle for the case of a short eccentric rod.

According to the diagram $\xi = r\sin(w+\delta)$ Page 43 Z. T. V. G.* the missing quantity is given as

$$z = \frac{r^2}{2l}\left[\cos^2\delta - \cos^2(w+\delta)\right]$$

or

$$z = \frac{r^2}{2l}(\cos^2\delta - 1) + \frac{r^2\sin^2(w+\delta)}{2l}$$

or

$$2lz = r^2(\cos^2\delta - 1) + r^2\sin^2(w+\delta)$$

Letting $C = r^2(\cos^2\delta - 1)$ and substituting ξ for its value, we have

$$\xi^2 = 2lz - C$$

the equation of a parabola whose ordinates are the theoretical travels of the valve from its center of motion, and whose abscissas are the missing quantities for the same.

The radius of curvature of this parabola at its vertex $= \frac{1}{2}$ the latus rectum or parameter, and is equal to l the length of the eccentric rod, and we can substitute an arc of a circle with the radius l for this parabola without appreciable error.

For the travel $\xi = o$

$$z = \frac{C}{2l} = \mp\frac{r^2}{2l}\sin^2\delta$$

For $\xi = r$

$$z = \pm\frac{r^2}{2l}\cos^2\delta$$

For $z = o$

$$\sin^2\delta = \sin^2(w+\delta)$$

Therefore $w = o$

That is to say, the "missing quantity" disappears on the dead points since the valve is *actually set for equal leads.*

To lay down the actual curves of valve travel, the "missing quantity" being taken into account.

Fig. 3. With a radius OL_0 and the center O describe an arc L_0L to intersection L with the diameter of the valve circle OP_0. At the point O, and at right angles with OP_0, draw the indefinite line OZ.

With a radius of compass $= l$, and

* Abbreviation of Zeuner's Treatise on Valve Gears.

with the center on the line OZ, describe through L and L_1 the arc QLL_1Q_1. The ordinates to this arc from the line OP_0 measure in quantity and direction the values of the "missing quantity," which must be added to or subtracted from the theoretical radius vector, in order to obtain the true curve of the motion of the valve.

Fig. 3, for the purpose of showing an extreme case, has been laid down to scale as follows:

Eccentricity$=r=2$ inches.
Angular advance$=\delta=30°$.
Outside lap$=e=0.82$ inches.
Width of port$=a=0.75$ inches.
Length of eccentric rod$=l=8$ inches.

The construction for the missing quantity, for the sake of clearness, has all been added in heavy lines.

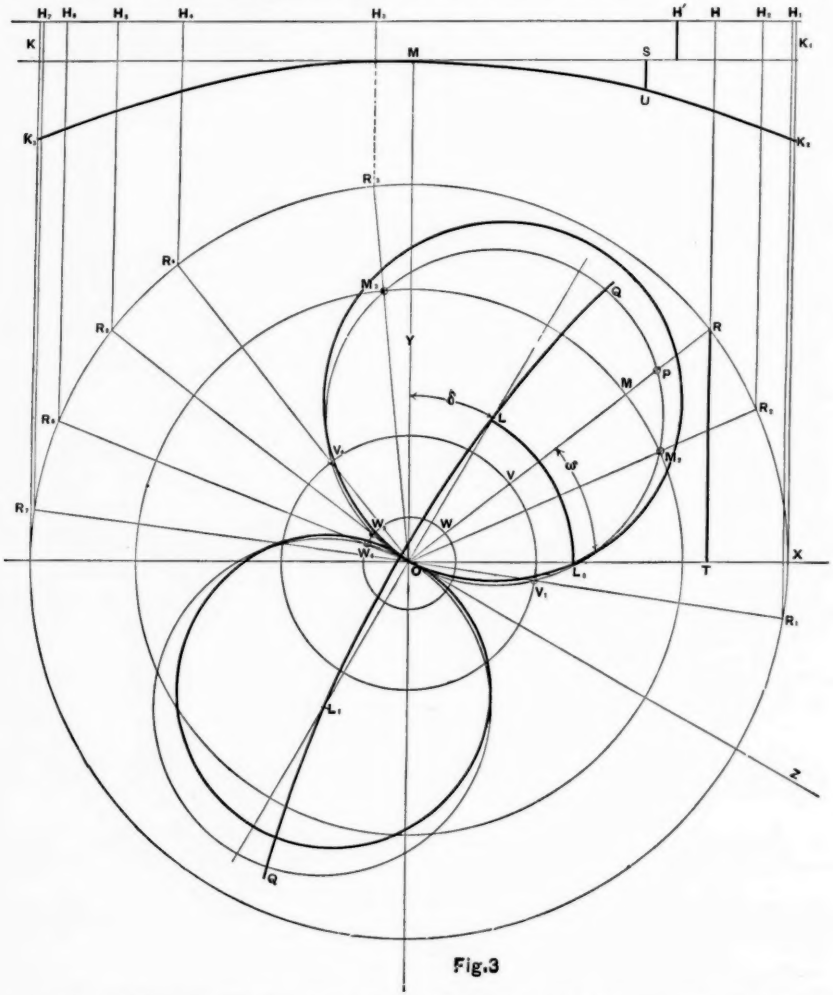

Fig. 3

The effect of the "missing quantity" when considerable enough to be noticed, is when the piston head moves towards the crank shaft, the cylinder being at the right hand.

(1) To delay slightly the pre-admission of steam.
(2) To increase the over-travel.
(3) To hasten the cut off of the steam (very slightly).
(4) To hasten the compression of the steam.
(5) To hasten the release of the steam.

When the piston head moves away from the crank shaft.

(1) To hasten the pre-admission.
(2) To diminish the over-travel.
(3) To delay the cut off (very slightly).
(4) To delay the compression.
(5) To delay the release.

A glance at the diagram at once reveals the fact that equalizing the lead very nearly equalizes the cut off.

It is only when the valve is set for equal extreme travels from the center that different laps are required. No attention has been paid to the variation in position of the piston due to the obliquity of the connecting rod.

III. THE PISTON'S POSITION.

The effect of the obliquity of the connecting rod is to keep the piston nearer to the crank shaft when it is moving away from it, and to draw it closer to the crank shaft when it is moving towards it, than it would be if the connecting rod was constantly parallel to the center line of the cylinder.

At the dead points, the connecting rod being in the center line of the cylinder, this action ceases.

Letting w = angle of the crank
" R = radius " "
" L = the length of the connecting rod.

We would have, if the connecting rod were constantly parallel to the center line of the cylinder, for the space passed over by the piston head = S

$$S = (1 - \cos w)R$$

and when we take the obliquity of the connecting rod into consideration

$$S_1 = R(1 - \cos w - L\left(1 - \frac{\sqrt{L^2 - R^2 \sin^2 w}}{L}\right)$$

Then for the difference d between the two positions we have

$$d = S - S_1 = L\left(1 - \frac{\sqrt{L^2 - R^2 \sin^2 w}}{L}\right)$$

or expanding

$$d = \frac{R^2}{2L} \sin^2 w \text{ approximately.}$$

Fig. 3. The positions H_1 to H_7 can be corrected by laying down in the opposite direction from the cylinder—from the points as already found the values of d.

It will be observed that the equation for d is the equation of a parabola whose semi-latus rectum is equal to L. Further, for $w = o$ or $180°$ $d = o$. If for this parabola we substitute the osculatory circle of a radius L to its vertex, we are practically close enough.

If now with a radius of compass = L, with one point in M and the other on the line YO bisecting the cylinder we describe the arc K_1K_2, we have, with sufficient approximation, the desired parabola.

Taking off for the position OR of the crank the distance RT = R sin w, and laying it off from M to S we have the correction SU of the position of the piston H, which, if we consider the cylinder at the right hand side, should be laid off to the left of H, giving the true position of the piston head at H′.

Thus we can lay down graphically the actual positions of the piston, and the true distances of the slide valve from its center of motion, *when set for equal leads* for every position of the crank, and for any proportions of the mechanism.

For the sake of emphasis, we again repeat: *Different laps are not necessary when the valve is set for equal leads, when the piston position is disregarded.*

Altering the laps will alter the leads. If the piston position is regarded and the alteration in the leads is disregarded for the sake of a very accurate cut off, the lap should be shortened on the side towards the cylinder, and lengthened on the side away from the cylinder. These amounts can be determined from the diagram.

It is only in the case of a very short connecting rod that such a procedure is necessary; short eccentric rods do not require it.

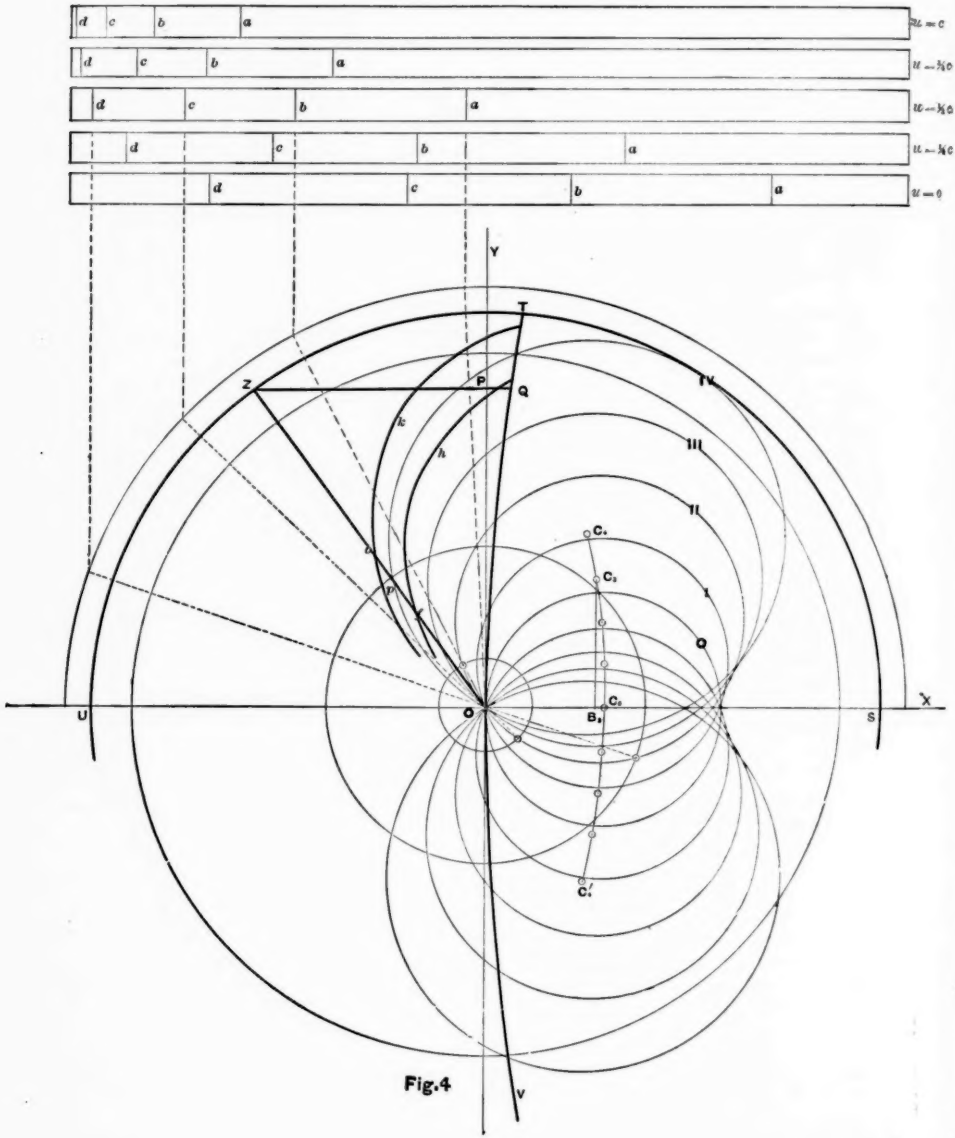

Fig.4

IV. The Stephenson Link Motion. Error Due to an Imperfect Mode of Attaching the Link to the Eccentric Rods.

On pages 56 to 98 of Z. T. V. G. the Stephenson Link Motion is very fully treated for both open and crossed rods, and for both forms of link, shown in Fig. 2 *a* and *b*, no distinction being made between them.

In Fig. 2 *a*, it will be observed that the rods are attached on the concave side at the points C and C_1, introducing an error which we will next endeavor to determine.

Fig. 4 is the Zeuner diagram, carefully laid down for the dimensions already given of the model, on which was used a form of link shown Fig. 2 *a*.

The method of making the slide valve describe its own diagram has already been explained. It is only necessary to add that as the drawing board turns synchronously with the crank, that the valve circles (curves) will both be on the same side of the origin instead of on opposite sides, as drawn for the sake of clearness in Fig. 3.

The object of making the link of the form Fig. 2 *a* is two-fold. First, to reduce the eccentricity, second, to enable us to place the valve wholly under the control of one eccentric rod.

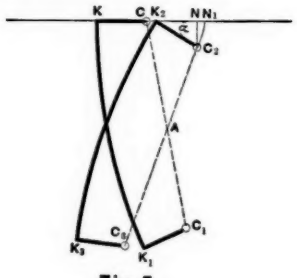

Fig. 5.

Fig. 5 is a center line sketch of Fig. 2*a*, similarly lettered; it will be observed that as the suspended link sweeps to and fro with a scythe-like motion, the line KC forms an angle with the horizontal line KN_1, which is approximately equal to the angle α, which the chord of the link forms with the vertical.

The value of $\sin\alpha$ is given with very close approximation on page 61 equation (11) Z. T. V. G.

As our only object is to point out an error which can be avoided, we will only make use of the principal term of this quantity, and take

$$\sin\alpha = \frac{r}{c}\cos\delta\sin w.$$

Let us denote the missing quantity due to this error by $z_1 = NN_1$, its effect being to keep the link closer to the crank shaft except where it equals zero.

Let $KC = q$

$$NN_1 = z_1 = q(1-\cos\alpha) =$$

$$q\left(1-\sqrt{1-\frac{r^2}{c^2}\cos^2\delta\sin^2 w}\right)$$

or expanding the quantity under the radical, and neglecting terms containing greater than the second power of the circular functions, we have

$$z_1 = \frac{qr^2}{2c^2}\cos^2\delta\sin^2 w$$

For $w = 90°$ this quantity is a maximum, and for $w = o°$ it is equal to zero. That is, it does not appear in the lead when the valve is set for equal leads, but it does attain its maximum near the point of usual cut off, and is particularly pernicious there and at the point of exhaust closure. The reason that it has remained unperceived hitherto is probably because it does not appear in the lead.

Transposing, we have

$$r^2\sin^2 w = \frac{2c^2}{q\cos^2\delta}z_1.$$

The equation of a parabola whose ordinates are $r\sin w$ and whose abscissas are z_1, its semi-latus rectum is $\frac{c^2}{q\cos^2\delta}$ which is also the radius of curvature of the osculatory circle to its vertex.

A moment's reflection will convince the reader that the error due to Zeuner's missing quantity is inappreciable (where of any consequence) in the present case. See Fig. 3 and explanation.

To determine the error z_1. Through O (Fig. 4), with a center on OX produced,

describe an arc of a circle TOV with a radius $=\frac{c^2}{q\cos^2\delta}$. With O as a center and the radius r describe an arc STU. Draw any position of crank as OZ to intersection Z with the arc STU. Parallel to OX draw through Z the line ZQ. which is the radius of the arc VOQT.

Laying down after the manner described, the arcs *bk fh*, we have the corrected circles for the valve motion at the IV grades. These arcs are laid down for the neighborhood of the point of cut off only.

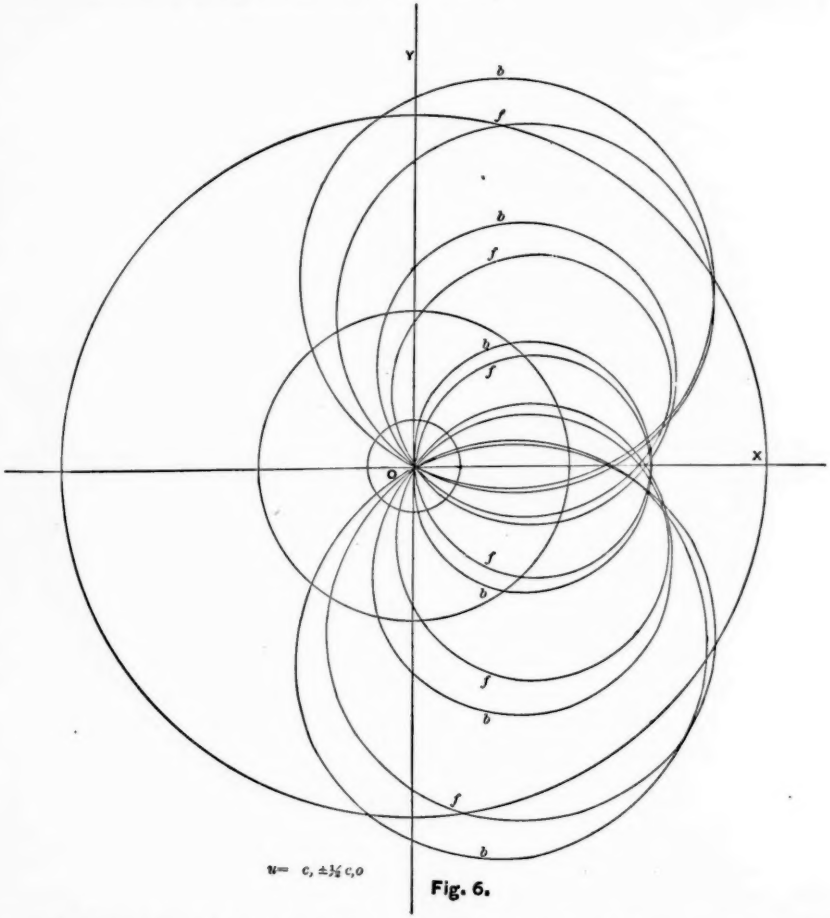

Fig. 6.

The distance PQ=the error which can be laid off both inside and outside the theoretical valve circle, as at *pf' pb*. In the model $q=3$ inches, $\delta=30°$ and $c=5.9$ inches.

Therefore

$$\frac{c^2}{q\cos^2\delta}=15.47 \text{ inches.}$$

This most pernicious error can be avoided by use of the link, Fig. 2 *b*, although a larger eccentric is required, and, therefore, it is sometimes difficult to fit into confined spaces. Certainly it is of great importance to avoid so faulty a construction if it be possible.

Figs. 6 and 7 are diagrams automatically traced by the working model.

To avoid the errors due to suspension, the link block was clamped in the link for each grade, and the link, therefore, swung upon the rocker shaft arm.

To avoid the errors due to the "lost motion" the valve circles were traced twice by reversing the direction of the motion, and the mean between the two circles traced with pen and ink by hand, the difference was very slight, if any at all.

It will be seen that these actual valve curves verify with great accuracy the corrected valve circles, Fig. 4 for the fourth grade.

Similar corrections can be made for each grade of link if desired.

The letters *f* and *b* refer to the direction of motion of the piston head. Forward (*f*) meaning toward the crank shaft, and backward meaning away from the crank shaft. A rocker shaft intervened reversing the direction of motion of the valve.

When the form of link shown, Fig. 2*b*, is used, the increased eccentricity required will increase the "missing quantity" given by Prof. Zeuner, and it must, therefore, be guarded against, particularly in extreme cases.

Cases may occur when it will prove advantageous to attach the eccentric rods to the link at points nearer its center than the extreme limits of the travel of the link block, but special pains should be taken to place the center of the pin joint on the central arc of the link; this method of attachment, how-

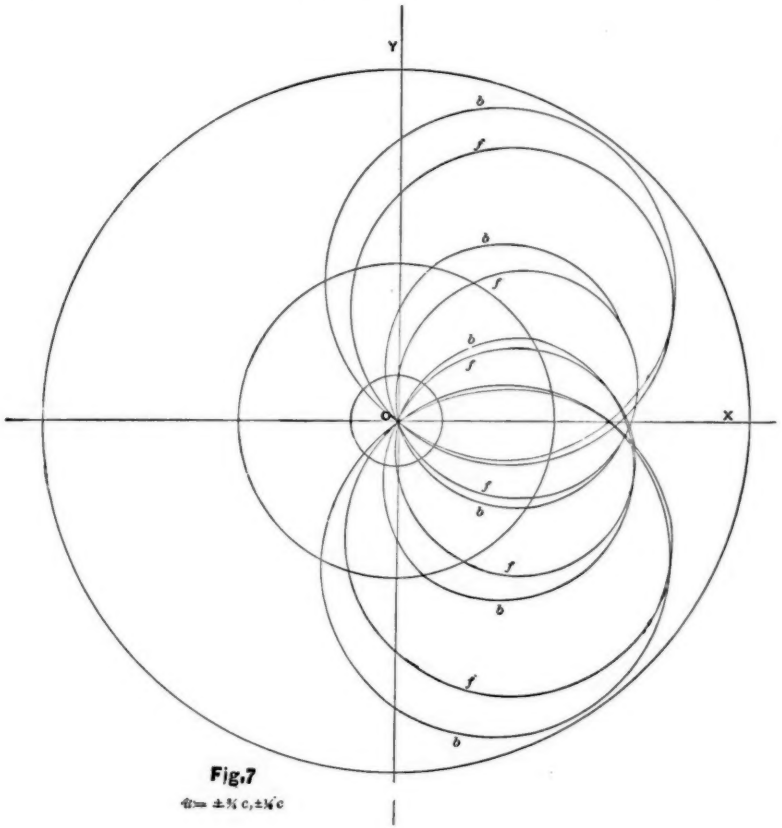

Fig. 7

$\phi = \pm \frac{1}{16}c, \pm \frac{1}{8}c$

ever, will result in increasing the slip of the link block.

V. Slip of the Link Block.

Zeuner gives two cases of the suspension of the link, by means of a hanger attached at the center of the chord of the link, and at the bottom of the link; in the first case the upper end of the hanger should theoretically move in an arc of a circle which has for a radius the length of the eccentric rod, and whose center is above the center line, a distance equal to the length of the hanger. The lower end of the hanger should be attached at the center of the link and on the central arc of the link, thus placing the origin of the arc of suspension at a horizontal distance equal to the length of the eccentric rod from the center of the crank shaft. Fig. 8 will render this clear. J_1 and not J should be the point of attachment of the hanger, and L not K_1 should be the center of the arc in which the upper end of the hanger E should move.

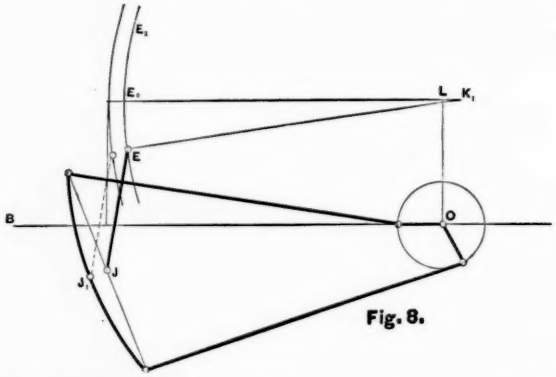

Fig. 8.

We can thus avoid increasing the slip by the quantity $\overline{JJ_1} \tan \alpha$ in one direction, and decreasing it by the same amount in the other direction.

Fig. 9 shows the second method of suspension of the link, by a hanger attached to the bottom.

Both of these methods are fully explained by Zeuner, and the reader is referred to his work for further details.

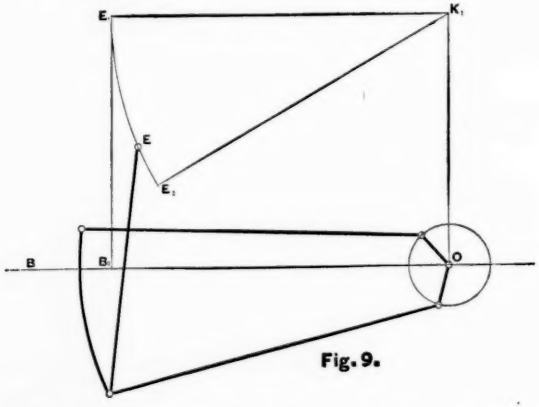

Fig. 9.

It will be perceived that the hanger is but a rude approximation to a parallel motion, used only because of its simplicity and lightness when the link block is forced to move to and fro in a straight line.

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When the link block is attached to the end of a rocker-shaft arm, as is commonly the case for American locomotives, if the hanger is made the same length as the rocker-shaft arm there will be no slip when the link block coincides with the point of suspension, the slip for other positions of the link block will be due to the angular position of the link.

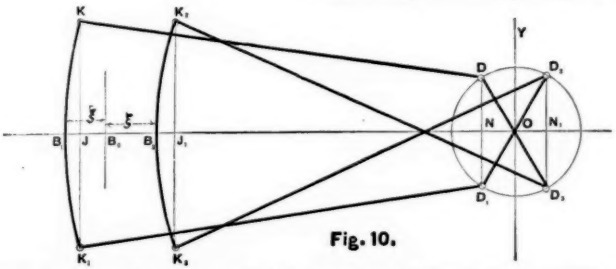


Fig. 10.

Assuming, when the block is forced to move in a straight line, that some method has been adopted to force the point of suspension of the link to move in an, at least very close approximation to a straight line, and, further, that when the link block moves in an arc of a circle of a given radius, that the hanger is of the same length as this radius, we can consider the slip as due only to the angular position of the link.

Of course these conditions cannot always be fulfilled, but it is best to know what ought to be done, even if we cannot exactly do it.

Fig. 10 shows the two positions of the links KK_1 and K_2K_3, for which the slip is zero, and letting s equal the amount of slip for all other positions, if we suppose the hanger attached to the middle point of the link, and u the distance of the link block from that point, we will have

$$s=(\sec a-1)u$$

or since the angle a is always very small

$$s=u(1-\cos a)=u(1-\sqrt{1-\sin^2 a})$$

and substituting for $\sin a$ its value and expanding and neglecting all terms containing higher powers than the square of the circular functions, we have

$$s=\frac{ur^2}{2c^2}\cos^2\delta\sin^2 w$$

We thus see that the effect of the slip does not appear in the lead, but being a maximum for $w=90°$ or $270°$, will affect

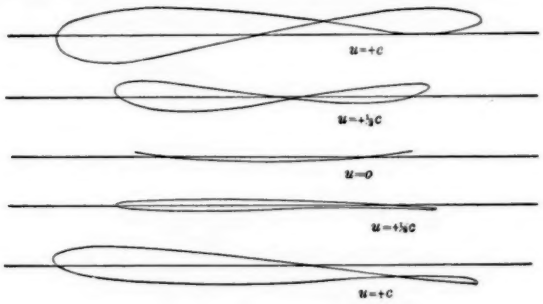


Fig. 11.

the points of cut off and exhaust closure.

Increasing the angular advance diminishes the slip, as also does increasing the length of the link. The tendency of the slip is to increase the travel of the valve by an amount V.

$$V=\frac{ur^2}{2c^2}\cos^2\delta\sin^2 w$$

This amount is very small for a well-proportioned valve gear, but it increases

directly as the distance u from the point of attachment of the hanger to the link.

When the link is suspended from the bottom, the value u must be replaced by $(c+u)$.

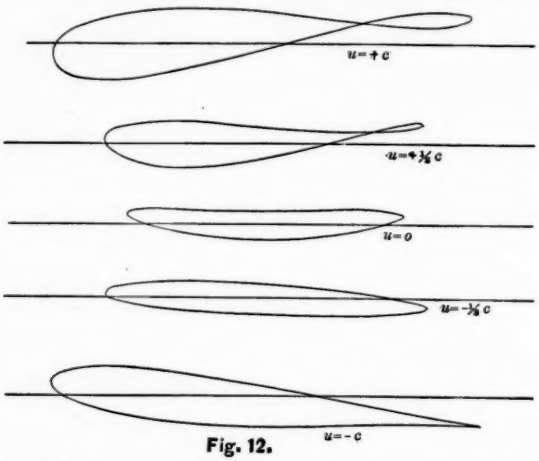


Fig. 12.

We thus see that for general usage at all points suspending the link at the middle is the best, while if one particular point is expected to be constantly used, and the other points only exceptionally, it is best to attach the hanger to the link at that point.

If the tumbling-shaft arm cannot be made equal to the length of the eccentric rods, and for obvious reasons it rarely can be so proportioned, the center of the tumbling shaft must be so placed as to make an arc, struck with its arm as a radius, intersect the theoretical arc at the point or points of greatest usage.

From what has been said about the position of the arc of suspension, it will readily be perceived that its length on either side of the horizontal line $E_0 K_1$, Figs. 8 and 9, is determined by the point of attachment of the hanger to the link.

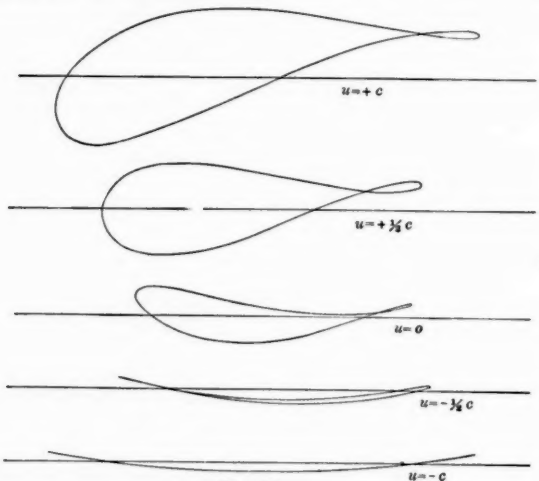


Fig. 13.

The link motion on which experiments were made with a view to testing the correctness of these results, had the following dimensions:

Length of eccentric rods=l=18 ins.
Radius of eccentricity=r=1¼ "
Length of link=2c=6 "
Angular advance=δ=30°
Open rods.

These results verify the above theory only in a qualitative way, as the upper end of the hanger was not always kept on the true arc of suspension.

inserted merely for the purpose of showing an imperfect mode of suspension. All of the slip curves are bad, and at no point is there any cessation of the slip.

Case III. The link suspended at the bottom. Fig. 13 reveals the fact that the slip becomes very great for the upper end of the link, so great as to seriously affect the distribution of the steam. The lower half of the link only can be relied upon for accurate work.

Case IV. The link suspended half way between the bottom and center. Fig. 14 shows a better average result than

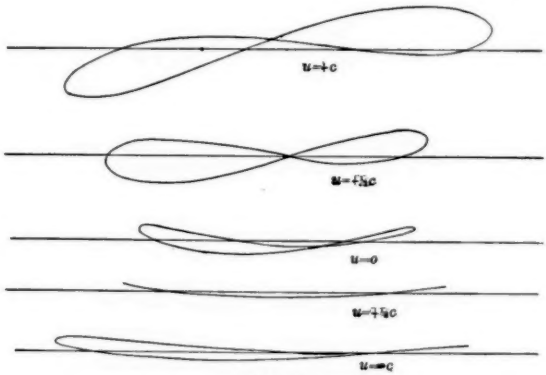


Fig. 14.

The link being suspended after the manner described a pencil was fixed in the link block, and the block successively fixed at different grades, the pencil being allowed to trace on a paper back of it, the curves of slip.

Case I. The link suspended at the center of its arc. Fig. 11 shows that the slip of the block increases both ways from its center, as had been predicted. The arc for u=o is the standard with which the other curves must be compared.

Case II. The link being suspended at the center of its chord. Fig 12 is inany of the others, and is undoubtedly the best mode of hanging the link when the grade $u=-\frac{1}{3}c$ is to be generally used. Viewed from a practical point, slip is of great importance, being the cause of the wear upon links, which soon unfits them for accurate work. Great pains are taken to reduce this wear by case-hardening the links, or using steel in the place of wrought iron.

A proper mode of suspension is the most important point to be attained when the durability of the link motion is under consideration.

DESICCATING THE BLAST OF BLAST-FURNACES.

The process for desiccating the current of air supplied to blast-furnaces, patented by Mr. W. H. Fryer, of Coleford, Gloucester, having been referred to in a correspondence which recently appeared in our columns, and some interest having in consequence been awakened respecting it, we place before our readers

a description of the invention to which we add some observations upon the subject by Mr. Fryer. The majority of our readers need hardly be reminded that, in the ordinary method of manufacturing iron, the blast-furnace in which the iron ore is reduced is urged by a blast of atmospheric air. A blast of atmospheric air is also employed in the treating of iron by the Bessemer process for the production of steel, as well as in cupolas and refineries, in which iron is melted for casting and for refining. The blast employed is drawn direct from the atmosphere, and contains a greater or less amount of the vapor of water, varying with the hygrometrical condition of the atmosphere from time to time. This vapor undergoes decomposition in the furnace, causing an absorption and loss of heat, varying from time to time in proportion to the greater or less amount of vapor thus introduced in the blast. The hydrogen evolved by the decomposition referred to gives a porosity to the iron or steel under treatment, which is very injurious in castings.

Mr. Fryer's invention consists in the desiccation of the blast so as to prevent loss of heat, and thus to economize fuel and promote rapidity of fusion and a regular working of the furnace, and also to prevent to some extent the porosity produced in the iron or steel made with air containing vapor of water. In practice, the air to be forced into the furnace, or Bessemer converter, is passed over sulphuric acid or chloride of calcium, so as to deprive the air of the vapor of water contained in it. The desiccating material is disposed in a chamber through which the air is passed, the particular arrangement depending upon the nature of the material employed (whether solid or liquid) and its desiccating and other properties, the essential conditions of the arrangement being that the desiccating material shall expose a large surface to the air, and that the capacity of the chamber shall be such that the air will travel through it at a sufficiently slow rate to insure the thorough action of the desiccating material upon it.

Such, briefly, are the principles of Mr. Fryer's invention, the description of which may be appropriately supplemented by the following considerations, on the application of desiccated air to the blast-furnace, from the pen of the inventor:

The total quantity of heat evolved by the combustion of the carbon of the fuel, added to that introduced by the preliminary heating of the blast, is already more than sufficient, after deducting the quantity absorbed as latent heat in the zone of fusion, to heat the iron and slag-forming materials up to their melting points; a large surplus escaping thereafter from the furnace top.

The heat so produced in the hearth is practically divisible into two portions or quantities: (1.) The sum of the heat at and below the temperature requisite to fuse the materials in question. (2.) The sum of the heat above such temperature. The former passes without absorption as latent heat, and therefore without melting effect, through the zone of fusion; becoming subsequently only partially absorbed in raising the said materials to the melting point in the upper part of the furnace. The latter is alone absorbed by the previously heated materials and effects their fusion. As the former is already in excess, the rapidity of the fusion, and consequently the "make" of the furnace is determined primarily by the latter, and increases in direct ratio therewith.

The practical bearing of this will, perhaps, be more clearly seen when regard is had to the narrow limits between the ordinary temperature in the furnace hearth and the temperature at which fusion commences. Increase of the furnace make must be sought by adding to this excess of the actual over the absolutely required temperature. The desiccation of the blast effects such addition, or what is the same thing, prevents the absorption of the heat caused by the dissociation of the aqueous vapor in the hearth of the furnace; heat which, as Mr. Lowthian Bell remarks, "is absorbed where it is most wanted" (*i. e.*, in the hearth) "and evolved where its presence is a questionable benefit" (*i. e.*, in the upper part of the furnace).* In order to compare the additional heat thus thrown into the hearth with the available excess previously existing there, take, for example, the following case referred to by Mr. Bell†: Furnace 11,500

*Journal of Iron and Steel Institute, No. 1, 1871; p. 198.
†Journal of Iron and Steel Institute, No. 2, 1871; p. 279.

cubic feet capacity; making No. 3 pig iron from calcined Cleveland ironstone, and producing 30.4 cwt. slag per 20 cwt. pig iron. The heat absorbed by the dissociation of the H_2O in blast (taken at an average of 0.74 cwt. per ton of iron) is estimated by Mr. Bell at 2720 units centigrade per 20 units of pig iron made.

In estimating the total heat absorbed by the materials fused, Mr. Bell does not distinguish between the heat absorbed in melting, as latent heat, and the heat absorbed in the upper portion of the furnace in raising the materials to the melting point. In order to arrive at the former, recourse is had to the data adopted by M. Schintz in his "Researches on the Blast Furnace," and accordingly the heat absorbed in actually melting is as follows:

Iron, 20 units $\times 175 = 3500$
Slag, 30.4 " $\times$ 60 $= 1824$

Total latent heat = 5324 units.

whilst (as above shown) the heat absorbed by the decomposition of the aqueous vapor in the blast amounts to 2720 units, or 51 per cent. as much heat as the total amount actually expended in melting. Compare this with actual results. By observations extended over a period of five years the late Mr. Truran, at Dowlais, found that, under otherwise similar conditions, the excess only of the average percentage of moisture in the air in autumn over winter effected, in the ballast iron furnace, a diminution in the make of iron of 13 per cent. in quantity, besides producing an inferior quality of metal.*

According to Mahlmann† the mean temperature at Cheltenham (the nearest observed station to Dowlais), is recorded as follows: Autumn, 10.1 C.; winter, 3.8 C.; the weight of water required to saturate 1 cubic meter of air at these temperatures being 10.63 and 7.22 grammes, respectively. The table on p. 92 of the work above referred to gives the mean relative humidity at Halle as follows: Autumn, 79; winter, 83.70 per cent. of the amount required for saturation; whence the mean actual weight of moisture present is as follows: Autumn, 8.3977; winter, 6.0431 grammes per cubic meter. The mean weight of moisture present, therefore, in the air in winter is nearly 3-4ths of the weight present in autumn; and as the removal of the 1-4th (excess in autumn over winter) effected an addition to the furnace make of 13 per cent., the further increase due to the removal of the other 3-4ths would be $13 \times 3 = 39$ per cent.; making the total increase due to the complete desiccation of the blast $13 + 39 = 52$ per cent.

That the whole of the 2720 heat-units absorbed by the dissociation of the H_2O would be so much clear gain, is, of course, not strictly accurate; since the oxygen thus liberated would supply the place of an equal weight of atmospheric oxygen, and save the specific heat absorbed by its proportionate weight of nitrogen (in the case in point) 329 heat units; leaving, net, 2391 units. In smaller furnaces, however, requiring more coke, and, consequently, more blast, per ton, the heat absorbed by the dissociation of the H_2O would be proportionately greater.

The cost of desiccating the blast is practically limited to the cost of evaporating and re-fusing the chloride of calcium; or of re-concentrating the sulphuric acid, as the case may be; adding, of course, a small margin for the labor of charging, and for occasional repairs, and renewals for waste. That cost is, practically, the value of the fuel employed, or, in other words, the cost of the heat units absorbed in physically expelling the absorbed water from the desiccating material. But without at present entering minutely into this, or considering, on the other hand, the saving of interest and working expenses involved in an increased furnace make, it is self-evident that the heat units thus expended in simply expelling the water absorbed by the desiccating material, will be incomparably less than the heat units absorbed by the chemical decomposition of the same water, if allowed to pass into the hearth of a blast furnace. The saving of fuel should, of course, be in proportion. The various other advantages of an increased furnace make, and of at the same time avoiding the irregularities caused by daily variations in the hygrometrical condition of the blast,

* Iron Manufactures of Great Britain; 3rd edition, 1865; p. 94 *et seq.*
† Kämtz's Meteorology, translated by Walker; p. 181-2.

with their disturbing effect on the working of the furnace, will be well understood by all who have had experience in the matter. There still remain for notice some considerations on the application of the process for the special production of alloys of iron and manganese in the blast furnace. In this case the reduction to the metallic state of the oxides of the latter metal contained in the ore is obviously a primary necessity. But the heat absorbed in dissociating a given weight of manganese from its combined oxygen is considerably greater than the amount absorbed in dissociating an equal weight of iron from its combined oxygen. Manganese also requires for its fusion a much higher temperature than iron. Hence in the normal working of an ordinary blast furnace, however much oxide of manganese be introduced with the ore, it remains unreduced, combines, as protoxide, with the silica of the charge, and passes off in the slag.

It has also been maintained that the reduction of manganese is effected solely by solid carbon; that, unlike iron, its reduction is effected, not by the carbonic oxide in the upper portion of the furnace, but, at a later stage, by the unconsumed carbon in the lower portion. For this reason, also, a higher temperature is requisite; because the higher the temperature the more rapid the fusion of the lower layers of the charges, and, consequently, the more rapid the descent of the upper layers, thus adding to the height of the column of solid carbon in the hearth, and so prolonging the intimate contact of the unreduced oxide therewith, and promoting the reduction of the manganese and its consequent solution in the molten iron.*

The conditions, therefore, to be attained in the manufacture in the blast furnace of alloys of iron and manganese are: (1) A very high temperature in the hearth (to effect the reduction and fusion of the manganese); and (2) A highly basic slag (to prevent combination of the yet unreduced oxide of manganese with silica). But the more basic the slag, the more infusible it is; requiring, in such case, a proportionately higher temperature also; whilst from the fact of the greater amount of heat absorbed in the reduction of manganese, it is (as Prof. Akerman has pointed out) even more difficult to attain a given high temperature when reducing manganese, than when simply reducing iron. Such, in fact, is the difficulty and cost of maintaining the high temperature necessary for the reduction of manganese, that the consumption of coke in the manufacture of the best ferro-manganese is about four times more per ton than in the manufacture of ordinary pig iron, and the daily furnace yield about four times less; one-third or so of the total amount of manganese nevertheless passing off unreduced.*

Under such conditions, the importance of desiccating the blast, and thus avoiding the loss of temperature in the hearth, caused by the dissociation of its aqueous elements, is apparent. The adoption of this process would, at the same time, prevent the occlusion of the otherwise dissociated hydrogen in the resulting metal; thereby adding to its value for the production of steel, free from the hydrogen cells formed whilst cooling, and which constitute the so-called "blown holes" in ordinary castings.†

*Schintz on "Blast Furnace," pp. 3, 141.

*Article by Prof. Akerman, in *Iron* of January 30, 1880.

†Dr. F. C. G. Müller "Ueberdie Gasausscheidungen in Bessemergüssen."

The total extent of the ground occupied by the Brussels Exhibition is 300,000 square meters, and the area covered by the palace 70,000. The number of exhibitors is 7,000, or more than one for each 1,000 inhabitants in a population of about 6,000,000. Two of the pavilions are occupied by the two principal telephonic companies, who are competing at Brussels, Antwerp, and Verviers, where rival central offices have been built, and are besieged by a crowd of experimenters. The number of tickets sold at the gate is about 10,000 a day, which is considered a success. It was attempted to establish a captive balloon on the model of the large Giffard captive balloon on a reduced scale, the rope being only 300 meters long instead of 500, and the volume 8,400 cubic meters instead of 25,000. But in spite of this dimunition the balloon refused to go up, the hydrogen having been mixed with a large quantity of common air.

THE RELATIVE AMOUNTS OF WORK PERFORMED IN PROPELLING BOATS BY PADDLE-WHEEL AND BY CABLE.

By J. B. JOHNSON, Assistant Engineer of U. S. Lake Survey.

THE following discussion is an attempt at the solution of two problems, viz:

1. *What are the relative amounts of work performed in propelling a boat by a reaction from the water itself, and by drawing upon a fixed cable, for any rate of current, and for any speed?*

2. *What rate of speed will employ the minimum amount of work for a given distance by these two methods, for any velocity of current?*

It will be found that the second problem is a corollary to the first.

These problems have not only great theoretical and practical interest in themselves, but at this time derive a peculiar interest from the pending discussion concerning these two methods of navigation which are now in use on the Erie canal.

By *work* is meant force into the distance through which the force is made to act. The work required to raise 100 lbs., 1 ft., or 1 lb., 100 ft., is said to be 100 foot-pounds. Here the unit of work is 1 pound raised 1 foot, or a foot-pound. *In the following discussion, the unit of work is the amount required to draw a given boat by cable in still water one mile, at the rate of one mile per hour.* The work required to do this will be called 1. To draw the same boat two miles at the same rate, would employ twice the amount of work, or work=2. Here the force has remained the same, since the rate is the same, but the distance through which it acted has changed. To draw the same boat 1 mile at twice the rate, or at the rate of 2 miles per hour, would require four times the amount of work, or work=4. Here the distance has remained the same, but the force has changed, since the rate is twice as great.

It is a recognized principle in dynamics, that when a body moves through a constant fluid medium, the resistance it encounters is directly as the square of its velocity.*

The work done in propelling a boat at a uniform speed is simply overcoming the resistance to its motion. This resistance varies as the square of its velocity through the water. Therefore, the work done, or fuel consumed, in propelling a boat *over a given space*, varies as the square of the velocity of the boat. If, however, we are treating of the amount of work done *in a unit of time*, or horse power, we find it increases as the *cube* of the velocity. For the force increases as the square of the velocity, and the distance traversed in a unit of time increases as the first power of the velocity, and hence their product, or the work done in a unit of time, increases as the cube of the velocity.

When a boat is drawn by cable, the *force* is the tension on the cable, and the *distance* through which it acts is the distance the boat moves *with reference to the cable.*

When a boat is propelled by a reaction of the water, the *force* is the same as though the boat were drawn at the same rate by cable, and the *distance* through which it acts is the distance the boat moves *with reference to the water from which the force reacts.* Thus when a boat is propelled through the water by paddle wheel or by screw, the wheel imparts to the water a motion, and this moving water reacts against the wheel, and this reaction propels the boat. Therefore the distance through which the force acts, in this case, is the distance the boat moves with reference to the moving water which reacts against the wheel. This backward motion imparted to the water is called the *slip.* The slip is about 25 per cent. of the motion

* See Price's Calculus, vol. III., sec. 267, and Morin's Mechanics, sec. 299 *et seq.* In the former it is derived theoretically, in the latter empirically, from experiments on boats drawn in water.

of the wheel in a well-proportioned boat in large channels, but sometimes becomes as much as 50 or 60 per cent. in confined channels like canals.

MOTION UP STREAM.

If two similar boats, one drawn by a cable and the other propelled by a wheel, move up stream against a constant current at the same rate, the forces required to propel them will be equal. The distance through which the force acts, for the boat drawn by cable, will be the distance the boat actually moves up stream, the same as before. With the self-propelling boat, the distance through which the force acts is the distance moved up stream + distance the current has run in that time + the slip.

This may perhaps be made clearer by an illustration:

1. If a man, weighing 150 pounds, climbs a stairway 12 feet high, he raises his weight through 12 feet, and performs 1800 foot-pounds of work.

2. If he raises his body the same distance by climbing up a rope, he again performs 1800 foot-pounds of work.

3. If the rope has a downward motion, such, that while he is climbing it moves down 6 feet, he has to climb 18 feet, and performs 2700 foot-pounds of work.

4. If the rope moves down 6 feet, and he also slips back 25 per cent. of all he climbs, then in order to raise his body through the given 12 feet, he must climb 12 feet + 6 feet + 6 feet = 24 feet, and must perform 3600 foot-pounds of work.

The first case corresponds to the boat drawn by the fixed cable, the fourth to the self-propelling boat.

MOTION DOWN STREAM.

If two similar boats move at the same rate down stream with a constant current, the forces required to propel them are again equal. The distance through which the force acts, for the cable boat, is the distance it travels, the same as up stream. The distance through which the force acts, for the self-propelling boat, is now the distance the boat travels—distance current has run in that time + the slip.

From this we conclude that the work done by the self-propelling boat is always greater than that done by the boat drawn by cable, when moving in still water and up stream; and that it is greater when moving down stream when the slip is more than the current; when the slip is less than the current, the cable boat does more work than the self-propeller.

The exact relations of the amount of work performed by the two systems are given by the following

FORMULÆ:

Let f = force required to draw given boat by cable one mile per hour in still water.
s = distance in miles.
v = velocity of boat through the water in miles per hour.
r = rate of current in miles per hour.
u = " " speed " " " "
t = time in hours.
Wc = work performed, or fuel consumed, by cable boat.
Wp = work performed, or fuel consumed, by screw or paddle boat.
a = 1 + percentage slip is of boat's motion (when slip = 25 per cent. $a=\frac{4}{3}$).*

Then

I. IN STILL WATER.

(*a*) *For a given distance.*

$$Wc = fsv^2 \quad . \quad . \quad . \quad . \quad (1)$$
$$Wp = afsv^2 \quad . \quad . \quad . \quad (2)$$

(*b*) *For a given time.*

$$Wc = ftv^3 \quad . \quad . \quad . \quad . \quad (3)$$
$$Wp = aftv^3 \quad . \quad . \quad . \quad . \quad (4)$$

II. UP STREAM, AGAINST A CURRENT r.

(*a*) *For a given distance.*

$$Wc = fsv^2 = fs(u+r)^2 \quad . \quad . \quad . \quad . \quad (5)$$
$$Wp = af(s+rt)v^2$$

But

$$t = \frac{s}{v-r}$$

therefore

$$Wp = afs\left(1 + \frac{r}{v-r}\right)v^2 \quad . \quad . \quad . \quad (6)$$

$$= afs\,\frac{v^3}{v-r} = afs\,\frac{(u+r)^3}{u} \quad . \quad . \quad (7)$$

(*b*) *For a given time.*

$$Wc = ftv^3 \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

* Since slip is wheel's motion—boat's motion, if the slip is one-quarter of the wheel's motion, it is one-third of the boat's motion.

$$Wp = aft\left(1+\frac{r}{v-r}\right)v^3 = aft\frac{v^4}{v-r} \quad \ldots \quad (9)$$

III. DOWN STREAM WITH A CURRENT r.

(a) *For a given distance.*

$$Wc = fsv^3 = fs(u-r)^2 \quad \ldots \quad (10)$$
$$Wp = af(s-rt)v^2$$

But

$$t = \frac{s}{r+v}$$

therefore

$$Wp = afs\left(1-\frac{r}{v+r}\right)v^2$$
$$= afs\frac{v^3}{v+r} = afs\frac{(u-r)^3}{u} \quad \ldots \quad (11)$$

(b) *For a given time.*

$$Wc = ftv^3 \quad \ldots \quad (12)$$

$$Wp = aft\left(1-\frac{r}{v+r}\right)v^3$$
$$= aft\frac{r^4}{v+r} \quad \ldots \quad (13)$$

Equation (7) when solved for minimum becomes

$$3v^2(v-r)-v^3 = o$$
$$2v-3r = o$$

whence $v = \frac{3}{2}r \quad \ldots \quad (14)$

Thus we see, from eq. (14), that the most economical rate for a self-propelling boat to move up stream is at a speed through the water equal to one and one-half times the rate of the current, or it moves up stream at one-half the rate of the current. This is also shown by the curves.

RESULTS.

If we let the unit of work (or of fuel) be that required to draw a given boat 1 mile by cable in still water at the rate of 1 mile per hour, and assuming a slip of 25 per cent. for paddle or screw-boats, whence $a = \frac{4}{3}$, eqs. (5), (7), (10) and (11) give the following tables of work by substituting values for u and r.

It will be seen that these tables are not intended to give absolute values for work, or consumption of fuel, for any given case, but only relative values for the same boat by the two methods.

It might seem unnecessary to give a table of work done by the cable-drawn boat, since it is always equal to fsv^3, but for the purposes of ready comparison it is given below.

It may also be remarked that the work required to draw a boat by pulling on a fixed cable is the same as that employed in drawing same boat at same rate by horses on the tow-path; so that all the following tables and curves of work for cable apply equally to a boat drawn by horses. This equality, however, is only in the amount of work performed. Since the character of the power is different; an equality of work does not imply an equality of cost, which is implied in the case of the two steamboats.

The curves of work given below are plotted from these tables of coördinates. Each column gives a separate curve. The four curves in Plate I are the plots of columns 1 and 5 of Tables I and III. The four in Plate II are from columns 2 and 5 of Tables II and IV.

In these curves the work is plotted for ordinates, and the speed of the boat for abscissas. The speed is its rate through the water, plus or minus the rate of the current ($u = v \pm r$).

WORK IN STILL WATER.

Curves 1 and 2, Plate I, show the relative amounts of work required for the cable and paddle-wheel boats, respectively, in still water. These curves are both parabolas, the ordinates of 2 being always $\frac{4}{3}$ of those of 1. This difference is simply the slip of the paddle or screw-wheel boat.

Therefore, in still water, if the slip is 25 per cent., a boat may be drawn at any given rate by cable for $\frac{3}{4}$ of the expenditure of fuel that would be required for a self-propelling boat. If the slip is 50 per cent., it would require but half the fuel.

WORK IN GOING UP STREAM.

Curves 3 and 4, Plate I, show the relative amounts of work performed, or fuel consumed, by a cable-drawn and a self-propelling boat respectively, when moving up stream against a current of four miles per hour.

Curve 3, work by cable, is the same parabola as curve 1, but its axis is now moved 4 units to the left.

Curve 4, work for self-propeller, has a point of minimum at $u = 2$, which is in accordance with eq. (14), and becomes tangent to the axis of ordinates at $+\infty$. It is therefore an asymptote to that axis.

TABLES OF WORK PERFORMED, OR FUEL CONSUMED IN GOING 1 MILE WHEN BOAT IS DRAWN BY CABLE FOR DIFFERENT RATES OF SPEED AND OF CURRENT.

TABLE I.—UP STREAM. Eq. (5) $Wc=fsv^3=fs\ (u+r)^3$.

Rate of Speed in mi. pr. hr. $=u$.	Still Water. $r=o$.	$r=$ 1 mi. pr. hr.	$r=$ 2 mi. pr. hr.	$r=$ 3 mi. pr. hr.	$r=$ 4 mi. pr. hr.	$r=$ 5 mi. pr. hr.	$r=$ 6 mi. pr. hr.
0	0	1	4	9	16	25	36
1	1	4	9	16	25	36	49
2	4	9	16	25	36	49	64
3	9	16	25	36	49	64	81
4	16	25	36	49	64	81	100
5	25	36	49	64	81	100	121
6	36	49	64	81	100	121	144
7	49	54	81	100	121	144	169
8	64	81	100	121	144	169	196
9	81	100	121	144	169	196	225
10	100	121	144	169	196	225	256
11	121	144	169	196	225	256	289
12	144	169	196	225	256	289	324
13	169	196	225	256	289	324	
14	196	225	256	289	324		
15	225	256	289	324			
16	256	289	324				
17	289	324					
18	324						

TABLE II.—DOWN STREAM. Eq. (10) $Wc=fsv^3=fs\ (u-r)^3$.

Rate of Speed in mi. pr. hr. $=u$.	Still Water $r=o$.	$r=$ 1 mi. pr. hr.	$r=$ 2 mi. pr. hr.	$r=$ 3 mi. pr. hr.	$r=$ 4 mi. pr. hr.	$r=$ 5 mi. pr. hr.	$r=$ 6 mi. pr. hr.
0	0	—1	—4	—9	—16	—25	—36
1	1	0	—1	—4	— 9	—16	—25
2	4	1	0	—1	— 4	— 9	—16
3	9	4	1	0	— 1	— 4	— 9
4	16	9	4	1	0	— 1	— 4
5	25	16	9	4	1	0	— 1
6	36	25	16	9	4	1	0
7	49	36	25	16	9	4	1
8	64	49	36	25	16	9	4
9	81	64	49	36	25	16	9
10	100	81	64	49	36	25	16
11	121	100	81	64	49	36	25
12	144	121	100	81	64	49	36
13	169	144	121	100	81	64	49
14	196	169	144	121	100	81	64
15	225	196	169	144	121	100	81
16	256	225	196	169	144	121	100
17	289	256	225	196	169	144	121
18	324	289	256	225	196	169	144

TABLES OF WORK PERFORMED, OR FUEL CONSUMED, IN GOING 1 MILE WHEN BOAT IS PROPELLED BY WHEEL, FOR DIFFERENT RATES OF SPEED AND OF CURRENT.

TABLE III.—UP STREAM. Eq. (7) $Wp=\frac{4}{3}fs\,(u+r)^3$.

Rates of Speed in mi. pr. hr. $=u$.	Still Water. $r=0$.	$r=1$ mi. pr. hr.	$r=2$ mi. pr. hr.	$r=3$ mi. pr. hr.	$r=4$ mi. pr. hr.	$r=5$ mi. pr. hr.	$r=6$ mi. pr. hr.
0	0	∞	∞	∞	∞	∞	∞
1	1.3	11	36	85	167	288	457
2	5.3	18	43	83	144	229	341
3	12.0	28	56	96	152	228	324
4	21.3	42	72	114	171	243	333
5	33.3	58	92	136	194	266	355
6	48.0	76	114	162	222	296	384
7	65.3	98	139	190	254	329	419
8	85.3	122	167	222	288	366	457
9	108.0	148	197	256	326	406	500
10	133.3	178	230	293	366	450	546
11	161.3	210	266	333	409	496	596
12	192.0	244	305	375	455	546	648
13	225.3	282	346	420	504	598	
14	261.3	321	390	468	555		
15	300.0	364	437	518			
16	341.3	409	486				
17	385.3	457					
18	432.0						

TABLE IV.—DOWN STREAM. Eq. (11) $Wp=\frac{4}{3}fs\,\frac{(u-r)^3}{u}$.

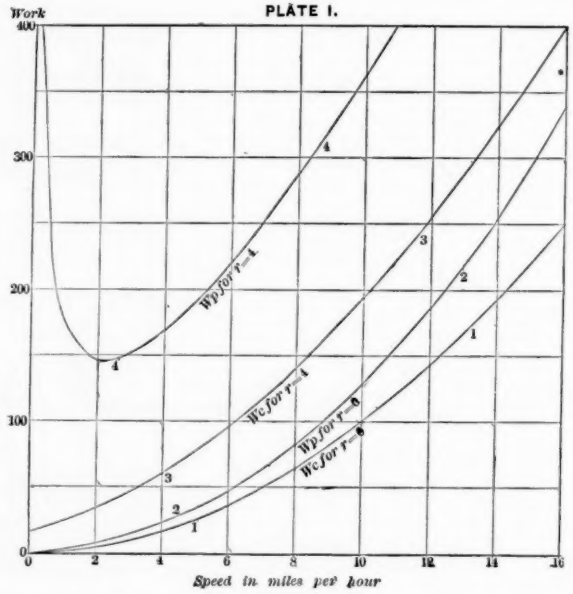
Rate of Speed in mi. pr. hr. $=u$.	Still Water $r=0$.	$r=1$ mi. pr. hr.	$r=2$ mi. pr. hr.	$r=3$ mi. pr. hr.	$r=4$ mi. pr. hr.	$r=5$ mi. pr. hr.	$r=6$ mi. pr. hr.
0	0	−∞	− ∞	− ∞	− ∞	− ∞	− ∞
1	1.3	0	−1.3	−10.7	−36.0	−85.3	−166.7
2	5.3	0.7	0	− 0.7	− 5.3	−18.0	− 42.6
3	12.0	3.6	0.4	0	− 0.4	− 3.6	− 12.0
4	21.3	9.0	2.7	0.3	0	− 0.3	− 2.7
5	33.3	17.1	7.2	2.1	0.3	0	− 0.3
6	48.0	27.8	14.2	6.0	1.8	0.2	0
7	65.3	41.1	22.4	12.2	5.1	1.5	0.2
8	85.3	57.2	36.0	20.8	10.7	4.5	1.3
9	108.0	75.9	50.8	32.0	18.5	9.5	4.0
10	133.3	97.2	68.3	45.7	28.8	16.7	8.6
11	161.3	121.2	88.4	62.1	41.6	26.2	15.2
12	192.0	147.9	111.1	81.0	56.9	38.1	24.0
13	225.3	177.2	136.5	102.6	74.8	52.5	35.2
14	261.3	209.2	164.6	126.8	95.2	69.4	48.8
15	300.0	243.9	195.3	153.6	118.3	88.8	64.8
16	341.3	281.2	228.7	183.1	144.0	110.9	83.5
17	385.3	324.8	264.7	215.2	172.3	135.5	104.4
18	432.0	363.9	303.4	250.0	203.3	162.7	128.0

By an inspection of these curves, we may derive the following laws:

1. *The work expended by drawing a boat a given distance up stream by cable is a minimum at a zero speed, and increases on the line of a parabola to* $+\infty$ *for an infinite rate of speed.*

2. *The work expended in propelling a boat a given distance up stream by paddles or screw-wheel, is* $+\infty$ *for a zero speed, decreases to a minimum for a speed equal to* $\frac{1}{2}$ *rate of current, and then increases to* $+\infty$ *for an infinite speed.*

PLATE I.



The relative amounts of work required by the two methods cannot be given in general, except that it is always less for the cable boat when navigating in still water or up stream. In still water the advantage over the self-propeller is 25 to 50 per cent. (the amount of the slip). From curves 3 and 4, Plate I (column 5, Tables I and III) we may see that, against a 4 mile current, for a speed of 2 miles per hour, the ratio of work by the two methods is as 36 to 144; for a speed of 4 miles, 64 to 171; for speed of 6 miles, 100 to 222; for speed of 8 miles, 144 to 288, &c. It is apparent that the advantage of the cable system increases rapidly with an increase of current. (The reader might construct curves from the other columns in Tables I and III, and see this increase more clearly).

ON THE ERIE CANAL.

The last New York State Engineer's Report shows that a screw propeller on the Erie Canal has a slip of about 40 per cent.; a in the above formulæ then becomes $\frac{5}{8}$ instead of $\frac{1}{2}$ as was used in the Tables. He also shows that the rate of current is about one-half a mile per hour. Substituting these values for a and r in eqs. (5) (7) (10) and (11) we have the relative work performed by the two methods of screw-propelling and cable-towing on the Erie Canal in going

AGAINST THE CURRENT.

Speed in miles per hour.	Work by Cable or Horses.	Work by Screw Propeller.
1	2	4
2	6	12
3	12	24
4	20	38
5	30	55
6	42	76

WITH THE CURRENT.

Speed in miles per hour.	Work by Cable or Horses.	Work by Screw Propeller.
2	2	3
3	6	8
4	12	18
5	20	30
6	30	46

We thus see that on the Erie Canal, in going against a half-mile current, the screw propeller expends about twice the work, and in going with the current about $\frac{3}{5}$ the work required to draw the same boat at same rate by cable or by horses. The question of economy, as between the cable and horses, is a practical one, with which we here have nothing to do.

THE MOST ECONOMICAL RATE UP STREAM.

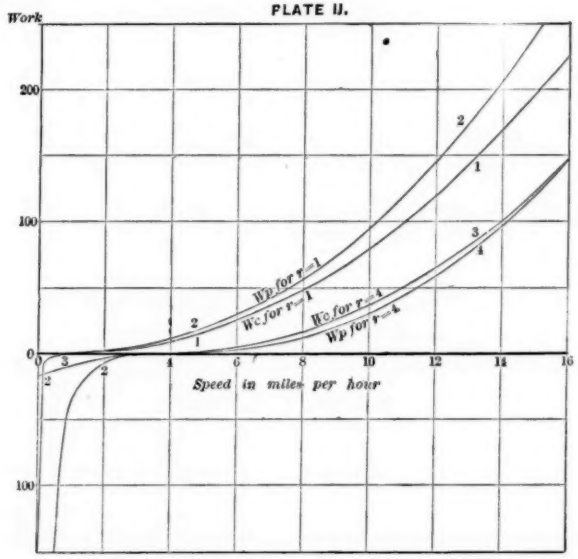
The fact, that the work required for a self-propelling boat to accomplish a given distance against current, tide, or drifting wind, is a minimum when the speed is one-half the rate of the opposing current, tide, or drift, is a very important one. It has, however, been observed before. Thus when time is not considered, but only the economy of fuel or of muscular energy, the most economical rate is as above stated. The same law obtains in the case of one vessel pursuing another. The pursuing vessel will overtake the forward one with the smallest expenditure of fuel when its rate is $1\frac{1}{2}$ times that of the forward vessel.

WORK IN GOING DOWN STREAM.

The curves in Plate II show the relative work by the two methods in going down stream. Curves 1 and 3 give the work by the cable system for rates of current of 1 and 4 miles respectively, and curves 2 and 4 for a self-propelling boat at the same rates. It will be seen that for a current of 1 mile per hour the cable boat always has the advantage, the work being always less. For a 4 mile current, the work is greater by the cable system up to a speed of 16 miles per hour. If all the columns in Tables II and IV were plotted, it would be seen that with a current of less than 2 miles per hour, the cable system still requires less work even in going down stream.

The parts of these curves, continued below the axis of abscissas, give the

PLATE II.



amount of negative work done by the boat when its speed down stream is less than that of the current. In this case, to reach a given distance down stream at a zero speed, the negative work by a self-propelling boat would be $-\infty$. The curves for the self-propelling boat, 1 and 4, therefore, are asymptotes to the axis of ordinates below the origin. Curves 1 and 3 are parabolas both above and below the axis.

HORSE POWER OF ENGINES.

By taking the equations of *work in a given time*, we would find the relative-sized engines required by the two methods for giving rates of speed and of current.

Thus, if we assume, for the sake of having a convenient unit, that it requires an engine of 1 horse-power to draw a given boat by cable at the rate of 1 mile per hour in still water, we obtain from eqs. (8) and (9) by making $r=\frac{1}{2}$ and $a=\frac{5}{3}$, for navigation on the Erie Canal.

AGAINST THE CURRENT.

Speed in miles per hour.	No. H. P. of Engine for Cable Boat.	No H.P. of Engine of Screw-wheel Boat.
1	3	8
2	16	33
3	43	83
4	91	171
5	166	304

It may be remarked, that in this discussion, no account has been taken of the additional work employed in handling the cable, but this would certainly be small. It has also been assumed that the cable-drawn boat was not one of a line of tows, but that it grappled the cable itself.

The work, in every case, has been computed for a given velocity, after such velocity has been acquired. The overcoming of the inertia of the boat in starting it has not been considered.

FUEL-GAS, AND THE STRONG WATER-GAS SYSTEM.

By Dr. HENRY WURTZ, New York City.

From Transactions of the American Institute of Mining Engineers.

HERACLITUS, a sage of antiquity, called the dark philosopher, who refused a throne, preferring a hermit's cell, propounded, twenty-four centuries since, the maxim:

War (or strife) engenders all things.

This, though probably intended by Heraclitus to apply especially to the internal forces of nature, is often said, with equal reason, of the affairs of men. Controversial strife, whether fortunately or unfortunately, is a crucible through which all new discoveries in science, and all technical applications of science must pass—a test which they must all endure before they can become so vitalized as to germinate, so to speak, take root in the human mind, grow up, and overspread the earth. The greater the number and the power of the elements arrayed against such a growth, and of the influences hostile thereto, the greater should be the inherent vitality of the germ, the more strenuous, skillful, and persistent its cultivators and upholders.

During the decade last past we have had, in spite of the severe stringency of the times, an active growth of this kind in progress, whose prospective importance it would now be difficult to overrate. This is the movement which has for its motive the idea that, generally speaking, *fuel should be gaseous in form*, and which has for its goal the introduction into general public use of gaseous products, made by cheap and rapid processes and on a gigantic scale, distributed throughout our cities and towns in distribution-systems, which shall be proportionately gigantic, and sold at prices which will bring such fuel within the means of the poorest householders.

Personally, for ten years past, the writer has never failed, on occasions public or private, to urge his belief that the realization of this idea, deemed by him a certainty of the future, will bring about important revolutions in human affairs. As once publicly stated, he looks upon it as "the next great stride

in civilization," destined to rank at least with the introduction of steam power, railway transportation, the Bessemer process, the electric telegraph, the articulating telephone, and the like events.

The time the writer has long looked for has now at length come, when "practical men" and "moneyed men" are working together, and organizing, on the basis of the production of gaseous products adapted or adaptable for *fuel*, without direct reference to the use thereof, in a merely vehicular way, as media of convection for illuminating hydrocarbons; this latter being regarded as only subordinate and not essential to the grand aim in view. This, of course, brings into prominence any improved plan that may be found to exist, of generating such gases cheaply and rapidly; and hence what is known as the "Strong Process" at once claimed and has received great and deserved attention.

It is, probably, not necessary that this process should now be described in detail, as Professor Silliman, at the Montreal meeting, explained it. Gentlemen desiring details will find them complete in a printed pamphlet, obtainable from M. H. Strong, Esq., 13 Park Row, New York city. The writer is now, for the first time, occupied in investigating, chemically, the operation and the products of the Strong apparatus; but this undertaking is yet too recent to have furnished many complete results. The present statement is, therefore, to be looked on as preliminary only. Experiments to determine directly the *practical* thermic effectiveness of the Strong gas—which is, for most persons, the point of most immediate interest—have not yet been made, though it is possible that some of them may be so in time to be printed with this paper. Results are here given, however, of careful analyses, together with determinations of density, of a sample of Strong gas; the two sets of figures agreeing with each other, as is essential to reliability. The data are thus at length at our command for accurate *theoretical* computations of the thermic energy, or energy of combustion of this gas.

The sample of gas examined is one now contained in a holder of 10,000 cubic feet capacity at Mount Vernon, Westchester County, N. Y. It was made some six weeks since, and has, therefore, stood for this period over water, though apparently without appreciable change in composition. The materials used were egg coal, one-third, and waste anthracite screenings, two-thirds. Two good analyses of this gas gave, for 100 volumes:

TABLE I.

	No. 1	No. 2.	Mean.	Density-computation.
Hydrogen	44.55	45.05	44.80	× .0006930=.0310464
Carbonic oxide	40.29	39.79	40.04	× .0096740= 3873470
Marsh gas	4.76	4.85	4.80	× .0055300=.0265440
Carbonic acid	1.11	1.21	1.16	× .0152000=.0176343
Nitrogen	9.10	9.18	9.14	× .0097134=.0887805
Oxygen	.19	.09	.14	× .0110560=.0015478
	100.00	100.17	100.08	

Computed density at 32° F. = .5529000
Four determinations of density by effusion at 32° F., gave a mean = .5512

Traces of sulphuretted hydrogen, doubtless present in this gas when first made, have been removed by the water. There is proof that the holder has otherwise preserved the gas well in the small amount of oxygen present. No diffusion outward could occur, without inward diffusion of air, carrying oxygen.

The above constitutes what may be regarded as a *verified* gas-analysis, agreeing with the experimental density.

In the next table will be found the

percentage composition by weight as well as by volume; also the thermic value, in Centigrade and Fahrenheit units, or degrees to which one pound (7000 grains) of water may be theoretically heated by one pound of gas.

TABLE II.

	By volume.	By weight.	Computation of thermic value per pound.
Hydrogen	44.80	5.62	×344.62°=1935°
Carbonic acid	40.04	70.06	× 24.03°=1683.5°
Marsh gas	4.80	4.80	×130.63°= 627°
Carbonic acid	1.16	3.19	
Nitrogen	9.14	16.06	Centigrade—4245.5°
Oxygen	.14	.28	Fahrenheit—7642°
	100.08	100.00	

One of the striking results of this analysis is the extremely large amount of nitrogen shown. This could only have come from air introduced in the process of manufacture, by reason of imperfection in the experimental apparatus used. This apparatus is so small that the duration of each heat or successive run is necessarily very short—only ten or twelve minutes, instead of thirty or more, as in a working apparatus. The contents of the generator, in products of combustion with air, after each blowing-up with the latter, are swept on to the holder, together with the gases or products of combustion with steam. The former bear, therefore, to the latter a considerable proportion, appearing to multiply the nitrogen threefold above its proper proportion.

It is the writer's expectation that a perfected fuel-gas production—such as will soon be brought about, now that this manufacture is to be prosecuted on a large scale—will give us a gas containing uniformly less than 3 per cent. of nitrogen by volume, or from 5 to 6 per cent. by weight. The nitrogen in the anthracite yields at most ½ per cent., while that in the steam is inappreciable. Such a gas as this, made with a perfected Strong generator, will have, as shown by the above analyses—taking into account that 6 per cent. of nitrogen implies an ingress of 7.5 per cent. of air, or 1.5 per cent. of oxygen, which has, therefore, given us 3 per cent. of the carbonic oxide present—the following composition:

TABLE III.

Computed composition of crude Strong gas, from large working generators.	Reduced to 100 volumes.	Density computation.	Computed to 100 parts by weight.	Thermic value.	
				Centigrade.	Fahrenheit.
Hydrogen..... 45.0	49.6	.0344	6 81	2,347°	4,225°
Carbonic oxide..... 37.0	40.8	.3947	78.11	1,877°	3,379°
Marsh gas..... 5.0	5.5	.0304	6.02	786.5°	1,415°
Carbonic acid 1.0	1.1	.0167	3.30	.....	.....
Nitrogen..... 2.7	3.0	.0291	5.76	.....	.....
90.7	100.0	D. = .5053	100.00	5,010.5°	9,019°

Or, in round numbers, such gas will have, at 32° F., half the density of air, with a total thermic power of 5000° C., or 9000° F. per pound. (At 60° F. the density will be only .4482). This standard should be obtained in fair practice; and, with good apparatus in good order, may be reasonably and uniformly expected for *crude Strong fuel-gas* made from two-thirds screenings, and one-third egg and *unpurified*.

A document referred to below contains

evidence that even the imperfect Mount Vernon apparatus has produced gas containing far less nitrogen than the sample analyzed by the writer. This is an analysis by the learned chemist, Dr. P. H. Vander Weyde, as follows:

Hydrogen	52.3
Carbonic oxide	39.4
Marsh gas	4.3
Carbonic acid, Nitrogen	4.0
Sulphuretted hydrogen	undetermined.
	100.0

The carbonic acid and nitrogen are here summed up together; but if the carbonic acid be assumed as found in the analyses of the writer the nitrogen becomes 2.9 per cent. only by volume.

The next tabulation represents the product as it will be after purification with lime to remove the 3.3 per cent. by weight of carbonic acid.

from an important document (not previously before the public), which contains results of experiments upon the amount and cost of production of gas from the experimental Strong apparatus at Mount Vernon, by highly competent gentlemen entirely disinterested in every way. These gentlemen were Charles A. Stanley, Esq., Assistant Superintendent of the Brooklyn City Gas Works, and Professor William D. Marks, of Philadelphia.

The report referred to was made by them August, 18, 1877, to the Brooklyn City Gaslight Company. A copy of this, evidently a *fac-simile* made by impression, has come into the writer's possession. It is this document that was found the valuable analysis, cited above, of Dr. Vander Weyde. There is copied, also, in this report, a series of experiments previously made by an agent of,

TABLE IV.

	By volume.	Density-computation.	Composition by weight.	Thermic value (Fahrenheit) per pound.
Hydrogen	50.15	.03475	7.04	4367°
Carbonic oxide	41.25	.39905	80.76	3493°
Marsh gas	5.56	.03075	6.22	1462°
Nitrogen	3.04	.02953	5.98	.....
	100.00	D. at 32° F. = .494 D. at 60° F. = .437	100.00	9322°

As less than 2 per cent. of the nitrogen out of the 6 per cent. by weight comes from the anthracite, a full economic view of this product requires further that, as 4 per cent. of the nitrogen costs nothing, it should also be deducted. Should it be found possible, therefore, to exclude air wholly, the thermic value of the resulting fuel-gas would be

$$9322° + 4 \times \frac{9322°}{100-6} = 9719°$$

So perfect a result as this is not, however, at present, counted on.

COST OF PRODUCTION OF STRONG FUEL-GAS.

Pending the experimental investigations on the thermic value of the Strong gas, which the writer has projected, and is now arranging to make, it may be of interest to present some points derived

and for, Walter E. Lawton, Esq., of No. 12 Cliff street, New York, of which latter experiments Messrs. Stanley and Marks remark that they do not give as good an average as their own. Mr. Lawton has since, it is understood, become interested as a promoter of the fuel-gas movement.

In each of these two series of experiments, consisting of a succession of ten-minute runs, the yield of gas ran down gradually. Stanley and Marks obtained at first 1647 cubic feet gas from 63 pounds anthracite, and 1627 cubic feet gas from 63 pounds anthracite. In the Lawton series were obtained 1718 feet from 60 pounds, and 1554 feet from 60 pounds, the mean of these four being 1000 feet from 37.5 pounds; while the tenth runs respectively gave Stanley and Marks 1050 feet from 45 pounds; Lawton, 1042 feet from 45 pounds; the

mean of the last two being 1000 feet from 43 pounds.

Messrs. Stanley and Marks state, however, that "the generator and flues are so small, and the doors so arranged, that the apparatus admittedly cannot run without choking from clinkers." Also: "The apparatus, being the first of its kind, is not so conveniently designed as it might have been; much trouble with clinkering of the fire might be avoided by a design which would admit of stirring the fire." Other imperfections, obvious to these skilled engineers, and readily remediable, are alluded to.

The writer feels perfectly justified, through his past experience in cases of this sort, which has been exceptionally extensive, in estimating the yield obtainable in a well-constructed working apparatus (such, for example, as is now erecting at Yonkers) from the *best* work actually accomplished with this imperfectly constructed experimental plant; which is, as above, 1718 feet from 60 pounds, or about 1000 feet from 35 pounds coal. For safety, however, let us rather adopt the *four best runs*, two of each set; giving 37.5 pounds per thousand as the yield that may be expected to be fully and continuously realized on a large scale from a perfected plant. The coal used by Stanley and Marks was about one-third egg (used in the generator), worth at that date $5 per ton, and two-thirds of a mixture of dust and pea (in the hopper), worth then $1 per ton. Strong prefers, for obvious reasons, that no pea coal should be used, but all dust or fine screenings, in the hopper; this two-thirds being, or rather including, that portion of the carbon which mainly reacts with the steam, and from which the gas therefore mainly proceeds. Such screenings—an unlimited supply of which, for a century, is procurable for the mere cost of transportation—may be rated at $1 per ton at most, while egg coal is now about $4.25, though to avoid cavil we will retain the valuation of $5. These data give, for 37.5 pounds anthracite per 1000 cubic feet of fuel-gas:

$$\frac{2240 \times 37.5}{\frac{500}{3} + 2\frac{100}{3}} = 3.605 \text{ cents; say } 3\tfrac{7}{8} \text{ cents.}$$

The minimum estimates of the Society of Gaslighting, discussed below, put this item at 75 pounds of anthracite at $4.50 per ton, about 15 cents per 1000 feet, which is 400 per cent. above the actual expense shown in the Mount Vernon generator, with a clean fire.

It is to be understood that the 37.5 pounds of anthracite includes *all* coal used for steam-making, and all other purposes in the Mount Vernon apparatus when working fairly. This is expressly set forth by Stanley and Marks; whose allowance, however, for coal consumption, being deduced from the *average* working of the partially clogged generator, during the whole succession of runs, sums up *six cents* per 1000 feet for coal (egg rated at $5). As to labor, in operating the experimental plant, Stanley and Marks state that an engineer at $2.50 per day, a stoker at $1.75, and a helper at $1.25, were occupied four hours and thirty-four minutes in making 13,035 feet of gas; hence they make for labor 17.5 cents per thousand; allowing, however, that "there can be no doubt that, if the process is worked on a large scale, the labor cost can be reduced much below this."

On this point the writer learns from James S. Pierson, Esq., the engineer engaged in constructing the new Strong Gas Works at Yonkers, that he expects these same three men to run at least four working generators, making 200,000 feet each per day of 10 hours, in all 800,000 feet, which will bring down the cost of labor per thousand to less than *two-thirds of a cent.* It is preferred to multiply this for safety, and call it a cent and a half per thousand. As to the statement of 3 men to 4 generators, the writer finds no difficulty in crediting this, as to his own personal knowledge 4 men do easily operate 6 Lowe generators.

Lime, and handling thereof, for purification of the fuel-gas, may cost, as a high figure for a moderate-sized plant, two cents more per thousand. We have, then, for the probable total cost of putting purified fuel gas, by the Strong system, into the holders: $3.67+1.5+2=$ say *seven cents and two-tenths per thousand feet.* Mr. Strong's own estimate has been *eight cents*, which is evidently an entirely safe one.

This will produce gas, as shown above,

of 9322° F. per pound; and as one pound of such gas at 60° F. contains (D.=437) just about thirty cubic feet, one cubic foot contains 311° F. of thermic power. The writer has reasons, from facts on record, to anticipate that, for heating water up to boiling, suitable burners will utilize for us at least 70 per cent. of this, or say 230° F. per cubic foot. When heating air, as in warming houses, even a larger proportion will be made available.

Among the newer chapters in the history of what has been called the Fuel-Gas War, is a pamphlet, issued recently by an association of gas engineers of the first rank, entitled "The Waste of Energy in the Production of Water Gas." To this document are signed the names of the members of this society, by way of indorsement.

The writer, on having his attention lately called to this pamphlet, found with surprise its arguments to be based almost wholly on assumptions which do not bear examination. Of these fallacies only a few of the more important can be selected, as a complete discussion of this document would probably more than wear out your patience.

The manifesto of the Society of Gaslighting begins by promising strict and impartial scientific discussion, and proceeds at once, then, to the usual reiteration of hackneyed denunciations of water gas. First, it is *not new;* reference being made to the well-known English patent to the Kirkmans, of July, 1852, in ignorance of the practically identical previous patent to F. C. Hills, of January, 1852, and of the closely approximate patents of 1845 to William Pollard and John Constable, with the American patent to George Michiels, also of 1845. The Kirkman patent serves to introduce what seems to be a declaration of the intention of the Society of Gaslighting when it shall come that its members shall be forced to make water gas, to do so without reference to existing patent-rights, assuming and asserting, in these words, that "the Kirkman process is that most largely used in this country," at the present day."

We next find reproduced the exploded assertion that water gas "was condemned and abandoned in France on account of it containing from 30 to 40 per cent. of the extremely poisonous carbonic oxide gas."

On the other hand, Dr. Adolphe Wurtz, one of the most eminent and learned of living chemists, wrote from Paris, June 12, 1878, in comment upon an investigation of the writer of one of the improved processes, and the attacks that were made upon it, as follows: "The use of water gas has never been prohibited in France, and if the numerous processes which have been indicated for its production have been abandoned, or have received only a restricted application, the cause is principally due to the circumstance that the technical and economical conditions of the production have, up to the present, been very unfavorable." He refers, of course, to the non-occurrence in France of indigenous materials suitable for this manufacture. He also says that "the danger (that is, of carbonic oxide in gas for domestic use), which could only produce ill results exceptionally and through fatality, has been exaggerated, and should not be taken into consideration." In reference to this part of the controversy, but two remarks will at present be offered.

Most gases, except pure air, are unfit for purposes of inhalation or respiration, and carbonic oxide shares this unfitness with others that are found in gas from gas coal. It is not, however, the purpose of the makers of fuel gas to introduce an article for purposes of respiration. Nor is it intended to serve out to the public an *inodorous* gas, as has been averred, thus increasing the liability of accident. All fuel-gas made for household or other uses will be found to possess odors even more characteristic and alarming than that of gas-coal gas. As to those cases coming under the head of fatalities, such as blowing out the gas in a sleeping-room, these will occur with all gases. So, also, will men go to sleep upon railroad tracks; but this has not been deemed an argument against the railway system. So will coal miners unlock and open their safety lamps; but no one therefore demands that coal mining be discouraged or discontinued. Moreover, carbonic oxide is actually now used, and far too largely and generally, for purposes of respiration; this being, in point of fact, one of those very lamentable defects of

our present household organizations which *fuel-gas is destined wholly to cure.* The leakages and irregularities of our coal stoves, heaters, and furnaces, which force us now so often to inhale carbonic oxide—together with other gases, such as *sulphurous oxide*, a compound more poisonous, beyond all comparison, than carbonic oxide—will be entirely avoided by the adoption of fuel-gas heaters of proper construction.

Again, it has been previously pointed out by the author, that risks from fire and explosion will be greatly less with carbonic oxide than with gas-coal gas, which latter contains from one-third to one-half of marsh gas, or *fire-damp*, this being much the most explosive of all common combustible gases.

The document emanating from the Society of Gaslighting then proceeds to its main business, which is to prove that, in the conversion of carbon into fuel-gas, less than one-third of the thermic power of the carbon is left, more than two-thirds being necessarily wasted or dissipated altogether. This is a great advance on the earlier arguments of the opponents of fuel-gas, who only went so far as to assert that, as water, when unburned, must necessarily absorb just as much energy as its hydrogen engenders when burned, therefore the whole project must be unwise, unscientific, unpractical, and utopian. Not longer ago than 1873, technical journals, held in high and just esteem as educators of the public in technical matters, and of great circulation, used language indicating that this sort of thing was to be classed with perpetual motion and the like delusions. To illustrate, the following may be exhumed: "Notwithstanding the reiterated statement in the *Scientific American*, and other exponents of practical science, that it is impossible to utilize water as a fuel, because it takes as much heat to decompose it into oxygen and hydrogen as one can get from the recombustion of these gases, men continue to waste their time in inventing apparatus to accomplish it."

It appears to have been almost universally conceded that the undeniable proposition, founded on the conservation of energy, implied in the last paragraph, in enforcing the conclusion that *some expenditure* must needs accompany the manufacture of water gas, made it self-evident that all such schemes were unworthy the attention of the public and of practical men. The unbiased portion of the public has now begun, however, to comprehend that the existing practical conditions really, and indeed overwhelmingly, neutralize this seemingly sound and scientific argument; that the economy of use, the controllability, purity, cleanliness, healthfulness, safety, comfort, uniformity, indestructibility, reliability, easier confinement and storage, and other merits of fuel-gas will justify, if necessary, *considerable expenditure* in the making of it; and that the assumed application to this case of the grand truth of the conservation of energy involves a practical fallacy.

A new and great change of base on the part of the enemy appears, therefore, to have been decided upon; and in this pamphlet the attempt is deliberately made to obtain credence and currency for an asserted demonstration—that the expense or "waste" in converting the thermic energy of carbon into a gaseous form must needs be something like two-thirds of the raw material or solid fuel started with!

First. There is presented a *theoretical* computation.

Anthracite is stated to have a total theoretical thermic power per pound of 13,000° F. In reality, 14,000° is nearer, but it is probably not worth while to correct this now. Its *practical* value (for steam purposes, for example) is rated, however, as low as 6000°F.* For making fuel-gas, it is claimed that steam of as high a pressure as 100 pounds, say 7 atmospheres, is essential, the total heat of which is rated at 1153.4° F. per pound, which is low (1182.5° being about true, according to Trowbridge), but for simplicity this may also be admitted. 16 pounds of carbon and 24 pounds of water (as steam) are said to make 1000 cubic feet of equally mixed hydrogen and carbonic oxide, which is near enough for 60° F. Such mixture, in equal volumes, if it were obtainable, would weigh 40 pounds, and contain $2\frac{2}{3}$ pounds hydrogen and $37\frac{1}{3}$ pounds carbonic oxide. According to the admitted conservation-

* For reasons apparent to an expert reader, they nevertheless rate *coke*—containing, as is well known, from 7 to 10 per cent. less carbon than good anthracite—at a practical value of 10,970° F. per pound.

of-energy theory, this hydrogen, in burning (from 32° F.), engenders $62{,}500° \times 2.66 = 166{,}250°$. Such temperature must therefore be supplied by combustion of carbon, in order, theoretically, to unburn or decompose the water from which the hydrogen proceeded. It is, however, necessary to concede that the 16 pounds carbon, in burning to carbonic oxide with the oxygen of the steam, furnish $4450° \times 16 = 71{,}200°$; so that the amount of additional carbon, or rather, anthracite, required theoretically, at 13,000°

$$\text{per pound} = \frac{166.250° - 71{,}200}{13{,}000°} = 7.31 \text{ lbs.}$$

The process of decomposition of steam by incandescent carbon is very strangely called *dissociation*. It may much more appropriately be called *combustion*, but we will not quarrel now with mere obscurities of language. So far, except fractional variations of data some of which may about balance each other, all is rational. And the result or product of the operation is 40 pounds of mixed hydrogen and carbonic oxide, but, theoretically, *at the temperature of* 32° F. An addition to the anthracite is, therefore, evidently necessary, determinable (with any degree of precision) only by experiment, representing what is necessary to heat the 40 pounds of gas, together with any *excess of steam* accompanying it, up to the temperature, above 60° F., at which they issue from the generator. This, at $500° - 60° = 440°$, in the Strong system, *may* be (see below) something under a pound; say .9 pound of coal. Then $16\frac{1}{9}^{6} + 7.31 + .9 = 26$ pounds of anthracite, in all.

This amount of anthracite, burned directly, has the theoretical value, $26 \times 13{,}000° = 338{,}300°$ F.; while 40 pounds of purified gas obtained therefrom, as above, in the Mount Vernon generator, have, according to the writer's analyses (see Table II.), deducting, of course, the 15 per cent. (at least) of nitrogen by weight which is not derived from the anthracite, the value $\frac{40}{40 - (15 \times 4)} \times 7642° = 359{,}633°$.

Here are two *theoretical* figures, which are directly comparable. Even if the value of 14,000° be assigned to the anthracite, we get then for total anthracite required, 25.4 pounds, and for its theoretical value, $25.4 \times 14{,}000° = 355{,}600°$ F., which is still some 4000° below the theoretical value of the Strong gas, theoretically obtainable therefrom. This curious fact is due, in some measure, to the considerable thermic value of the 5 per cent. of marsh gas present in the Strong gas, of which the Society of Gaslighting takes no account.

In the pamphlet, an addendum, ostensibly corresponding to the above, is made to the amount of anthracite theoretically required, in settling which "dissociation" is again mentioned, and to which the writer finds himself unable to attach any rational meaning whatever. The paragraph is as follows: "The temperature at which the dissociation of water takes place being 2192° F., according to Deville, the gas leaving the generator at this temperature, unless there be some method of utilizing the heat, carries off in heat, the temperature of the gas at the holder being 60° F.," an amount of the heat summing up 39,041° F. It seems to be asserted that the "temperature of dissociation" is that at which the gases *must* leave the generator. Now, while 2192° F. is less than half the temperature of dissociation *under constant volume*, according to estimates of Bunsen and Deville (4500° F., or higher), Deville obtained dissociation *under constant pressure* (that of the atmosphere) at some 1600° F. But it is wholly impossible to discern what we have to do with dissociation at all, or with any temperature, except the mean degree at which the products do actually leave the generator, of which more below.

The theoretical anthracite of the Society of Gaslighting adds up, including that which they insist on, for purposes of dissociation, to 28.31 pounds. Even this, at 13,000°, is theoretically worth only 368,030° F., not yet much above the theoretical value of the fuel-gas yielded by it theoretically (as above, 359,633°).

Second. The Society of Gaslighting estimates the amount of anthracite "practically required to produce 1000 cubic feet" of fuel-gas.

The assertion is started with, that this case is one parallel with that of the waste of thermic energy in the steam engine; rated in the pamphlet at nine-tenths of

the fuel. There is no parallelism whatever between the two cases. Thus, where shall we discover, in the fuel-gas process, anything parallel to the loss of energy in exhaust steam? To consider the fanciful arguments brought in at this stage of their figuring will somewhat tax your time and patience. It is first asserted that, instead of 24 pounds of water, as steam, being needed to make 1000 feet or 40 pounds of gas, 50 pounds of steam at least are necessary, or an excess of 26 pounds, which must accompany the produced gases, carrying off an immense quantity of heat, which, as asserted, is necessarily wasted. Even were this true, it would be easy to save much of this, if at the temperature asserted, 2192°, or any other, by simply passing it through the flues of a boiler, and bringing it down to 300° F. or thereabout. But the writer has only to refer here to the record, which shows that in the Lowe process at Utica in 1875, the amount of this excess of steam in the products, as they come from the generator, was determined by him by quantitative analysis, as only 10,772 grains, or 1.6 pounds per 1000 feet; thus increasing the amount of steam to be made and used to only 25.6 pounds. Therefore, the amount of coal required to make this steam, which they state at $\frac{1153.4° \times 50}{6000°} = 9.61$ pounds, is really more nearly $\frac{1153.4° \times 25.6}{6000°} = 4.92$ pounds. In the Strong system it appears unlikely that any appreciable excess of steam could remain in the gaseous products, as these, after their formation, are subjected to a secondary operation of transmission downward, through an incandescent mass of anthracite.

The 16 pounds of carbon is asserted to need 20 pounds of anthracite to supply it, an obvious exaggeration, 18 pounds being an ample allowance; if, indeed, in the case of this figure, any allowance is called for, except for impurity in the anthracite, which would bring it below 17 pounds; 18 pounds will, however, be conceded. The temperature of the gas, as it leaves the generator, is, *at one stage of* the Lowe process, sometimes as high as 1200° F. (its *mean* temperature, however, being as yet undetermined), but in the Strong experimental apparatus the eduction-pipe does not reach more than 500° F., so far as the writer's observation has extended, or as he can learn by inquiry from others. In the Strong process, then, the possible loss arising from this source (assuming that no means are taken to save this residual heat) may be computed as follows:

Hydrogen.....	2.66 pounds	×	(its sp. heat) 3.4046	×	(500°−32°)	=4,238°
Carbonic oxide.....	37.34 "	×	" " .2479	×	"	=4,332°
Steam.....	1.60 "	×	(its total heat at 500°) 1200°			=1,920°
Possible loss of heat per 1000 cubic feet of gaseous products,						=10,490°

To convert this into practical anthracite equivalent, the Society of Gaslighting would divide it by 6000, ignoring entirely the fact that this heat may fairly be all regarded as *recovered heat* of the products of combustion, recovered by the action of the regenerative appendage used in both the Strong and Lowe systems. Even if this be not insisted on fully, as the writer believes justifiable, yet the divisor 6000 is here of course absurdly inapplicable, and the lowest divisor that could be rationally adopted is the full assumed theoretical value, 13,000°. This makes the anthracite consumption due to residual heat $= \frac{10,490}{13,000} =$ .8 pounds; a figure to be substituted for the total figure ciphered out by the Society of Gaslighting, which is 8.35 pounds. Our total estimate of anthracite consumption in making 1000 cubic feet of Strong fuel-gas is then: 4.95+18+.8=33.7 pounds. This figure may be usefully compared with the best actual result on record of the very imperfect experimental plant at Mount Vernon=35 pounds; two-thirds of which were screenings.

According to the Society of Gaslighting, such weight of anthracite is practically worth 33.7×6000°=202,200° F., while 40 pounds Strong gas, made therefrom, as previously computed, is worth, *theoretically*, 359,633° F.; difference=157,433°.

It remains to be seen how large a percentage of this total theoretical value of 1000 feet of fuel-gas will be available when this gas is used for heating, cooking, motor, metallurgical, and other uses. It may be pointed out that only 55 per cent. of utilization = 195,982° F., pretty nearly obliterates the "waste of energy" of the Society of Gaslighting, when its own valuation of anthracite coal is adopted. Now it happens that 55 per cent. is just the proportion of the theoretical heat of gas-coal gases, stated by a distinguished gas chemist, Dr. Wallace, of Glasgow, the gas examiner of that city, to have been recently obtained by him in experiments in heating water, without the use of Bunsen burners. Moreover, our own very ingenious and industrious gas expert, Mr. Goodwin, of Philadelphia, has recently published experiments showing that, under the conditions of the Bunsen burner, some 25 per cent. less gas will do as much work in heating water below boiling, as when ordinarily burned.

Before leaving the pamphlet of the Society of Gaslighting, it is necessary to refer to the citation therein of some experiments by E. Vanderpool, Esq., and Dr. A. F. Schuessler, who made, as they state, a mixture of hydrogen 65 and carbonic oxide 35 per cent., and gave a determination of its thermic value as 136.6° F. per cubic foot. As *pure* hydrogen and carbonic oxide, in these proportions, must possess, at 60° F., a value per cubic foot of 324.5° F., this experimental result shows a utilization of but 42 per cent. of the total power. This, the pamphlet pointedly remarks, "may be taken as practically reliable." But, as no analytical or other evidence is presented of the absence of foreign inert gases from the mixture made, this surprisingly low result certainly justifies the presentment of the hypothesis of the ingress of such inert gases, in some such way as to evade the vigilance of these gentlemen. Few of the methods for the preparation of the two gases operated on yield products of even approximate purity.

The same experts also give a determination of the thermic value of gas-coal gas ("ordinary 16-candle gas") as 318° F. per foot; while in another part of the pamphlet (what is presumably) the same gas is rated at 660° F.; estimates of its economy as compared with so-called "water gas" being based on the latter figure, to the neglect of the former, arrived at by actual experiment.

The writer feels compelled also to refer to the fact that, in quoting the figures of Sarnstrom, from the correspondence of George S. Dwight, Esq., from Stockholm, Sweden, as given in the *Engineering and Mining Journal* of August 30, 1879, the writer or writers of the pamphlet would seem to have made an oversight, or selected figures to suit their argument. The result of comparing the Strong gas, as made at Stockholm, with gas-coal gas, are given by Mr. Dwight in three different forms, two of which agree with each other, and not with the third, which latter inferentially, therefore, involves some miscalculation. The two which agree give the fuel-gas a value of more than half that of the special gas-coal gas compared, while the other (the one selected and used in the Society's pamphlet) makes the gas-coal gas 2.2 times as powerful.

The following wonderful statement from this pamphlet of the Society of Gaslighting may help to account for the mental obliquities which must have contributed to the fallacious reasoning and untenable conclusions found therein: "A glass globe exhausted of air, under constant pressure and temperature, can be filled with the vapor of water, and there is still room for the globe full of alcohol vapor, and then there is still room for the globe full of ether vapor—and we might go still further." We might, in all humility, inquire what the gas analysts are to do, now that this new law of nature, subverting all their processes, has been discovered by the Society of Gaslighting?

A subsequent paper will be submitted on the relations of fuel-gas and the Strong system to *illuminating gas*, and to the closely related Lowe system of making the latter, in which facts and statistics of great public interest, now in the course of collection and preparation, will be brought forward.

ON THE MEASUREMENT OF DISTANCES IN LEVELING AND SURVEY OPERATIONS.

By Mr. HENRY V. WHITE.*

From "The Engineer."

THE object of this paper is to describe the principle and practical utility of a new self-measuring arrangement for calculating distances, capable of being attached at a nominal expense to the ordinary dumpy level or theodolite, by means of which the range and serviceable value of these instruments can be much increased. It is believed that by this arrangement the necessity of measuring with the chain in leveling for sections can be dispensed with. Moreover, the country can be surveyed at the same time with great accuracy, the combined operations being effected with rapidity and ease, while the results obtained will be found perfectly reliable for any surveys made for engineering purposes. Also, in taking flying levels on an open plain destitute of landmarks, the position of each spot where the staff has been held can be defined with great facility and accuracy. It is, moreover, claimed that while on uneven ground horizontal chain measurements are unreliable, the results thus obtained will be equally reliable whether the ground is flat or uneven.

The idea in the telescopic arrangement of estimating the distance of an object by means of the instrument itself is not original. The different distances require corresponding alterations in the focus of the object glass. Hence when the object is near the eye-tube must be drawn out, and when far pushed in. Dr. Brewster applied this fact to the measurement of distances, by having the eye-tube graduated accordingly. This, however, would vary for each observer, and, besides, the graduations would be so minute for appreciable distances as to be unreliable. The idea then suggested itself that if any suitable arrangement could be devised for estimating the distance of the staff used in leveling from the instrument itself, so as to dispense with the labor of chaining, it would commend itself to favorable consideration.

* Read before Institution of Civil Engineers in Ireland.

Now, in levels and theodolites the horizontal wire marks the intersection of the horizontal visual ray where it meets the staff when the bubble is brought to the center of its run, and is fixed in a diaphragm in the focus of the eye-tube and object glass.

In the following investigation the effect of the eye piece itself may be neglected, as the magnifying power affects in the same proportion both the image of the staff and the distance apart of the two new wires proposed to be fixed—one above, the other below the ordinary horizontal wire; these to be parallel to, and equidistant from, the latter, and in the same focus.

Let D = distance of staff from object glass, and d = that of conjugate focus; we have when f=that of principal focus

$$\frac{1}{d}+\frac{1}{D}=\frac{1}{f}$$

or

$$d=\frac{1}{\frac{1}{f}-\frac{1}{D}}$$

Now, if s=height of image of staff formed before being magnified by the eye piece at the focus of the object glass, we have when S=height of staff

$$S : s :: D : d.$$

Let H=difference of staff reading between these new wires, and w=their distance apart; then $S : s :: H : w$ or $H : w :: D : d$; substituting for d we obtain

$$H : w :: D : \frac{1}{\frac{1}{f}-\frac{1}{D}}$$

or

$$w=\frac{H}{\frac{D}{f}-1}=\frac{Hf}{D-f}$$

Hence

$$D-f=\frac{f}{w}\times H.$$

As $\frac{f}{w}$ is a constant, it is therefore

established that the distance of the staff from the object glass, less the focal length—which in ordinary instruments is about 12 inches—varies directly as the difference of readings between the upper and lower wires. To determine the actual value of $\frac{f}{w}$ when $D-f$ was found by measurement, experiments were made as follows, and the results obtained under the circumstances also serve to prove the practical value of the proposed adjustment. The instrument used is by Troughton & Simms, and the distance apart of the new wires was made about $\frac{1}{8}$-inch. The ground chained was not particularly flat, and the weather was unfavorable. The day was cloudy with occasional gusts of wind, which vibrated the instrument, accompanied with rain. There was no plummet used with the staff. The measured distances in the first column happen unfortunately to be uneven numbers, as in the actual measurement the chain was started from the perpendicular of the diaphragm on the ground, instead of 2 ft. farther on, so as to start from the focus.

Distance (D−f).	Difference (H).	Distance (D−f).	Difference. (H).
Feet.	Feet.	Feet.	Feet
48	0.47	148	1.47
53	0.52	198	1.95
58	0.58	248	2.45
63	0.62	298	2.94
68	0.66	308	3.03
73	0.72	348	3.45
78	0.76	388	3.80
83	0.82	398	3.93
88	0.87	448	4.40
93	0.92	498	4.90
98	0.96	508	5.00

Here throughout, as would be expected, the difference of readings varies as the distance—taking to allow for unavoidable errors of observation a mean of the results obtained from the readings 100 feet apart between 98 ft. and 498 ft. distance, we have

Distance (D−f).	Difference (H).	Constant $\left(\frac{f}{w}\right)$
Feet.	Feet.	Feet.
98	0.96	102.0
198	1.95	101.5
298	2.94	101.4
398	3.93	101.3
498	4.90	101.6

The mean of these results gives $\left(\frac{f}{w}\right)$ for this particular instrument $=101.6$; and since $101.6\times H=D-f$, we have a difference of reading amounting to

1 ft. corresponds to 101.6 ft. distance
and of $\frac{1}{10}$ ft. " 10.16 ft. "
and of $\frac{1}{100}$ ft. " 1.0 ft. "

To apply this rule:

Suppose H= 3.57 ft.
then $101.6\times3=304.8$ ft.
$10.16\times5=50.8$ ft.
$1.0\times7=7.0$ ft.

$362.6=D-f.$

From this it is evident that if we assume $\frac{2}{100}$ of a foot as the maximum error of observation likely to occur in estimating H in ordinary work, it will only give 2 ft. of possible error in the calculated distance; these slight inaccuracies would scarcely be sensible in practice, and would neutralize each other in numerous observations. Of course, in actual work, the distance should be taken from the center of the instrument itself, so that to $D-f$ as calculated should be added ($f+\frac{1}{2}$ length of tube)=usually to 18 inches. The following table gives opposite the actual distances ($D-f$) as measured the results as estimated:

Ascertained Distance(D−f)	Difference (H).	Estimated Distance(D−f).
Feet.	Feet.	Feet.
48	0.47	47.6
53	0.52	52.8
58	0.58	58.8
63	0.62	63.0
68	0.66	67.0
73	0.72	73.1
78	0.76	79.1
83	0.82	83.3
88	0.87	88.3
93	0.92	93.4
98	0.96	97.4
148	1.47	149.2
198	1.95	198.0
248	2.45	248.8
298	2.94	298.6
308	3.03	307.8
348	3.45	350.4
388	3.80	386.1
398	3.93	399.2
448	4.40	447.0
498	4.90	497.8
508	5.00	508.0

The result of these figures leads to no other conclusion than that the proposed system of measurement is perfectly reliable, even where great accuracy is required; in the latter case, by selecting a calm, clear day, and using a plummet, the estimated distances would be found more reliable than any measurements made with the chain on ground perfectly flat. When the principle of the proposed system of measurement was developed, the results were forwarded to Dr. Haughton, of Trinity College, who very kindly looked over the papers, and made the important suggestion that the best method of finding the constant for each instrument would be from direct measurement instead of the staff readings. The author, however, has had no means of doing so with the necessary accuracy.

Two special cases present themselves for consideration in the use of the adjusted instruments—one when they are applied to measuring purposes only, the other when levels and distances have to be taken at the same time. In the former case, with regard to the level, it should be placed in adjustment so as to intersect the staff in the usual way, and here, when the ground is tolerably flat, it will always be easy to make the three wires intersect. This is evident when we consider that the usual staff is about 14 ft. long, and that the greatest difference in the readings obtained in these experiments was 5 ft.—an amount that would never be exceeded in practice. It will sometimes happen, especially when long sights are used and the ground is tolerably uneven, that the three sights will not intersect simultaneously; this will only occur when the horizontal wire crosses either nearly the top or bottom of the staff. In this case the tube may be slightly raised or depressed so as to obtain the extreme readings without sensible error, as the angle will be very small, and the resulting distance will be perfectly accurate if the staff is gently waved back and forwards at the same time so as to obtain the lowest readings, as then the axis of sight will be perpendicular to that object. In the other case, when levels and distances have to be taken simultaneously, when the horizontal wire crosses in this manner so as to obtain only two readings, the distance can still be calculated from their difference, as it will be proportional though not quite so accurately; otherwise by taking the horizontal reading for leveling, then raising or depressing the tube as described for the distance, and then moving and adjusting the instrument for a back sight without disturbing the staff, we are enabled to make the extreme wires intersect so as to obtain the usual accuracy. With the theodolite this movement in the particular case described would be unnecessary, as the angle of elevation or depression could be made again horizontal by means of the screws; also with this instrument along sloping ground or the side of a hill the telescope has only to be raised or depressed through a known angle, from which the direct and also horizontal distances can be found. When the slope is very sensible the staff should be placed at right angles to the axis of sight, instead of being made perpendicular to the ground. It is desirable, when leveling for sections by this method, always, where possible, to fix the center of the instrument throughout in the line of the section, or where this is not possible, the following method may be advantageously pursued: Let A, B, C, &c., represent adjacent points in the line of the section, at convenient visible distances from each other; two ranging rods should be set up first at points A and B; let P then represent the position of the instrument. We then have the distances PA, PB, and the angle APB; consequently the distance AB. For intermediate observations it is easy to set up the staff exactly in the line of range as often as may be necessary. If a, b, c, &c., represent the position of these intermediate points, we can estimate the distances Pa, Pb, Pc, &c., which lengths can be marked off on the plan with a pair of dividers from P, so as to intersect the line of range A B. Thus the position of each intermediate point of observation can be accurately determined. Next a ranging rod should be fixed at C, and the levels between B and C could be similarly taken. It is desirable to use three ranging rods in setting out a straight line, the back pole being continuously transferred to the front according as the work progresses. Curves would, perhaps, be best set out

by actual measurements of offsets taken from points in the straight lines produced. In the field book, for use to correspond with the proposed adjustment to surveying instruments, it would be only necessary to have two extra columns for recording the intersections of the upper and lower wires. There is sometimes a column for entering the magnetic bearing; this would be requisite, or for entering in the case of the theodolite the bearing, or angles made with fixed points.

ON THE DERIVATION, OR DRIFT, OF ELONGATED RIFLED PROJECTILES.

By A. G. GREENHILL, M. A., Professor of Mathematics to the Advanced Class of Artillery Officers.

From Proceedings, Royal Artillery Institution.

THE principles of the preceding paper (see Sept. No. of MAGAZINE) afford an explanation of the drift of an elongated projectile to the right of the plane of fire.

If a projectile were fired in a vacuum, the axis would remain parallel to itself during the trajectory; no rifling would be required, and there would be no drift.

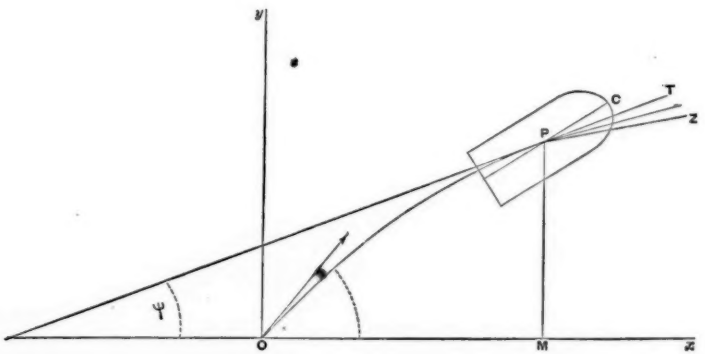
But it is observed that a projectile fired in air, with proper spin, has its axis in the tangent to the trajectory (very nearly) and that after it has reached a distance, short in comparison to ordinary ranges, from the muzzle, all "wabbling" ceases, being destroyed by the friction of the air, and the shot may be said, like a top, to "go to asleep."

Closer observation reveals that the point of the shot is a little above and to the right of the exact tangent to the trajectory; this deviation becoming more marked at the end of the trajectory.

A shot, even if perfectly centered, on issuing from the muzzle, has, after the first instant, its axis inclined to the tangent to the trajectory, in consequence of the curvature of the path of the center of gravity due to the action of gravity.

Take O, the origin, at the muzzle of the gun, Ox horizontal in the vertical plane of departure, Oy vertical, and Oz horizontal to the right of the plane of fire.

ELEVATION.



Let P be the center of gravity of the shot; x, y, z the co-ordinates of P; PC the axis of the shot; and PT the tangent to the path of P.

If there were no air, then PC would remain parallel to the tangent of the curve OP at O.

But the air causes a couple to act on the shot, tending to set the axis of the shot across the direction of motion; and this couple, acting on the shot (supposed to have angular momentum $c_s r$) about PC, will deflect the axis PC to the right;

and after a few gyrations, which are destroyed by the friction of the air, the shot will move steadily, with its point permanently deflected slightly to the right.

PZ (the direction of the resultant momentum Z of the body and the medium) will remain constantly parallel to the plane xOy, because there is no impressed force perpendicular to this plane; and if a be the angle the axis of the shot makes with the plane xOy, and if u, w be the component velocities of P along PA and PC, then, as before,

$$c_1 u = -Z \sin a,$$
$$c_3 w = Z \cos a,$$

and therefore the velocity of P in the direction Oz,

$$\frac{dz}{dt} = u \cos a + w \sin a$$
$$= Z\left(\frac{1}{c_3} - \frac{1}{c_1}\right) \sin a \cos a.$$

Now, the couple acting on the body in the plane APC is

$$(c_1 - c_3)\, uw = Z^2 \left(\frac{1}{c_3} - \frac{1}{c_1}\right) \sin a \cos a;$$

and this, acting on the resultant angular momentum of the shot (which may be taken to be $c_6 r$, and indifferently about the axis PC or PT, since they are very nearly coincident) will cause the point of the shot C to descend so as always to be very nearly in the tangent to the trajectory; and therefore if the tangent at P makes an angle ψ with the horizon,

$$-c_6 r \frac{d\psi}{dt} = Z^2 \left(\frac{1}{c_3} - \frac{1}{c_1}\right) \sin a \cos a = Z \frac{dz}{dt},$$

or

$$\frac{dz}{dt} = -\frac{c_6 r}{Z} \frac{d\psi}{dt};$$

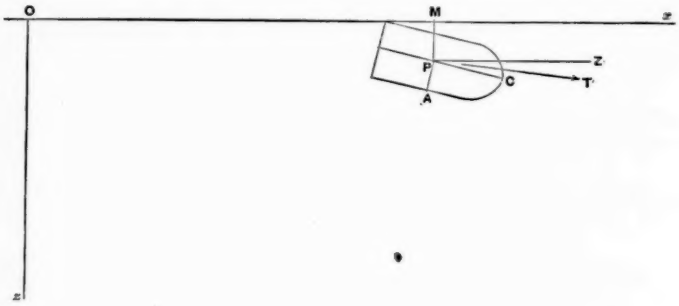
the negative sign being taken with $\frac{d\psi}{dt}$, because ψ is diminishing.

The resultant momentum Z may be put equal to Wv; where v is the resultant velocity in the trajectory, neglecting the momentum due to the motion of the air, which is small compared with Wv, the momentum of the shot; and therefore

$$\frac{dz}{dt} = -\frac{c_6 r}{Wv} \frac{d\psi}{dt} = -k^2 \frac{r}{v} \frac{d\psi}{dt}.$$

If the angular velocity r died away at the same rate as the linear velocity v,

PLAN.



the fraction $\frac{r}{v}$ would be constant, and equal to the value it has at the muzzle, namely, $\frac{\pi}{na}$; $2a$ being the caliber.

Then

$$\frac{dz}{dt} = -\frac{\pi}{n} \frac{k^2}{a} \frac{d\psi}{dt},$$

and

$$z = \frac{\pi}{n} \frac{k^2}{a} (\varphi - \psi),$$

if φ is the circular measure of the angle of projection.

On this assumption the drift would be proportional to the change of direction of the motion, and the total drift to the sum of the angles of ascent and descent.

Using u now to denote the horizontal component of the velocity,

$$\frac{dz}{du} = -\frac{\pi}{n} \frac{k^2}{a} \frac{d\psi}{du} = -\frac{\pi}{n} \frac{k^2}{a} g \frac{w}{d^2} \frac{(1000)^4}{Kv^4}$$

For resolving horizontally and normally,

$$\frac{du}{dt} = -\frac{d^2}{w} \mathrm{K} \left(\frac{v}{1000}\right)^3 \cos\phi,$$

$$v\frac{d\phi}{dt} = -g\cos\phi;$$

and dividing one equation by the other,

$$\frac{d\phi}{du} = g\frac{w}{d^2}\frac{(1000)^3}{\mathrm{K}v^4}.$$

In ordinary flat trajectories we may replace u by v, and then

$$\frac{d^2}{w}z = \frac{\pi}{n}\frac{k^2}{a}g\int_v^{\mathrm{V}} \frac{(1000)^3}{\mathrm{K}v^4}\,dv,$$

$$= \frac{\pi}{n}\frac{k^2}{a}\frac{\pi}{180}(\mathrm{D}_v - \mathrm{D}_{\mathrm{V}}) \quad \ldots\ (1)$$

This integral has been calculated by Mr. Niven for velocities from 900 to 1700 f.s., and is given on p. 78 of Major Sladen's "Principles of Gunnery," and he is at present engaged in extending the range of velocities from 400 to 2500, using the values of K lately determined by Mr. Bashforth from the experiments carried out in 1878 and 1879. ("Report on Experiments made with the Bash forth Chronograph, &c.," Part II.)

But it is more usual to assume that the angular velocity r dies away very slowly, so that we may suppose it constant, and equal to the value it has at the muzzle, namely, $\frac{\pi \mathrm{V}}{na}$; and then

$$\frac{dz}{dt} = -\frac{\pi}{n}\frac{k^2}{a}\frac{\mathrm{V}}{v}\frac{d\phi}{dt},$$

or

$$\frac{dz}{du} = -\frac{\pi}{n}\frac{k^2}{a}\mathrm{V}g\frac{w}{d^2}\frac{(1000)^3}{\mathrm{K}v^5},$$

and

$$\frac{d^2}{w}z = \frac{\pi}{n}\frac{k^2}{a}\mathrm{V}g\int_v^{\mathrm{V}} \frac{(1000)^3 dv}{\mathrm{K}v^5} \quad ; \quad \ldots\ (2)$$

so that we shall require the integral $\int_v^{\mathrm{V}} \frac{(1000)^3}{\mathrm{K}v^5}\,dv$ to be tabulated to calculate the drift.

The drift is proportional to $\frac{w}{d^2}$, which varies very nearly as the caliber, and also to $\frac{k^2}{a}$, which also varies as the caliber for similar projectiles; so that the drift varies as the square of the caliber for the same initial and final velocity. This explains why the drift is insensible in small arms.

The preceding explanation is substantially the same as that given by Prof. Magnus, except that the consideration of the *center of effort* is not necessary.

Magnus began by trying to explain the drift as due to the differences of pressure in consequence of the existence of a vortex round the shot; but this would make the shot drift to the *left*.

In the January, 1880, number of the *Messenger of Mathematics*, it is shown that a horizontal cylinder of density σ, revolving with angular velocity ω in infinite liquid of density ρ, and surrounded by a vortex, would, if left to itself, describe a cycloid from right to left, with mean velocity $\frac{\sigma-\rho}{2\rho}\frac{g}{\omega}$, and that if projected with this velocity would describe a horizontal straight line.

When a gas check becomes detached from the base of a shot, the forward motion is soon destroyed, but the angular velocity remains, and the gas check behaves in a similar manner to the above cylinder, and drifts to the left, with mean velocity $\frac{\sigma-\rho}{2\rho}\frac{g}{\omega}$.

For instance, in the 16 inch 80 ton gun

$$\omega = \frac{\pi}{n}\frac{\mathrm{V}}{a} = \frac{\pi}{50}\frac{1600}{\frac{2}{3}} = 48\pi,$$

and for copper,

$$\sigma = 8.6,$$

while for air, $\rho = .001276$,

therefore

$$\frac{\sigma-\rho}{2\rho}\frac{g}{\omega} = 715;$$

the mean velocity with which the gas check will drift to the left, if it becomes detached from the base of the shell.

It is only in such a case as this, then, that we can assert (as on p. 589, Vol. X., "Proceedings, R. A. Institution") that the drift diminishes as ω the angular velocity increases; and the paradoxical result that the velocity of drift is infinite when the angular velocity is zero, only means that we should require to project the cylinder from right to left with infinite velocity in order that the path should not be curved.

From the preceding explanation we see that the drift is proportional to the

angular velocity. This explanation is rendered necessary by the unfortunate mis-statement on p. 589, which was written down hastily, and of which the incorrectness escaped notice till after the paper was printed.

We can gain an approximate idea of the amount of deflection of the point to the right, and above the tangent to the trajectory, by considering them separately, each being supposed small. For if a' denote the angle between the axis of the shot and the vertical plane through the tangent of the trajectory, then

$$\tan a' = \frac{c_2}{c_1} \tan a,$$

and the couple acting on the shot about the axis normal to the trajectory in this vertical plane

$$= (c_1 - c_2) v^2 \sin a' \cos a';$$

which must therefore

$$= -c_6 r \frac{d\psi}{dt},$$

and therefore

$$\sin 2a' = -\frac{2c_6 r}{c_1 - c_2} \frac{1}{v^2} \frac{d\psi}{dt} = \frac{2c_6 r}{c_1 - c_2} \frac{g \cos \psi}{v^3}.$$

Again, if β' be the angle between the axis of the shot and the plane through the tangent of the trajectory perpendicular to the plane xOy, the couple acting on the shot about the axis PA

$$= (c_1 - c_2) v^2 \sin \beta' \cos \beta';$$

and this with our approximations must be put

$$= c_6 r \frac{da}{dt},$$

and therefore

$$\sin 2\beta' = \frac{2c_6 r}{c_1 - c_2} \frac{da}{dt}.$$

If the rifling at the muzzle be just sufficient for stability,

$$\frac{2c_6 r}{c_1 - c_2} = 8 \frac{c_3 c_4}{c_1 c_6} \frac{na}{\pi} \mathrm{V} = 8 \frac{n}{\pi} \frac{k_1^2}{k^2} a\mathrm{V},$$

with the approximations employed; and then

$$\sin 2a' = 8 \frac{n}{\pi} \frac{k_1^2}{k^2} a\mathrm{V} \frac{g \cos \psi}{v^3},$$

$$\sin 2\beta' = 8 \frac{n}{\pi} \frac{k_1^2}{k^2} a\mathrm{V} \frac{da}{dt};$$

and with our approximations we may put

$$\frac{da}{dt} = \frac{da'}{dt} = \frac{1}{v} \frac{d^2 z}{dt^2}.$$

TABLE OF THE INTEGRAL

$$Z = \int_{400}^{v} \frac{(1000)^5 dv}{\mathrm{K} v^5}$$ FOR INTERVALS OF 10.

v.	00	10	20	30	40	50	60	70	80	90
4	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
5	000000	062649	119267	170511	216995	259273	297828	333092	365442	395171
6	422556	447828	471182	492813	512885	531533	548879	565043	580136	594258
7	607494	619908	631560	642504	652794	662474	671583	680158	688241	695871
8	703084	709905	716352	722444	728200	733648	738807	743685	748297	752654
9	756777	760680	764376	767865	771154	774255	777178	779937	782541	785006
10	787337	789537	791620	793593	795461	797234	798916	800512	802027	803467
11	804837	806139	807376	808545	809621	810582	811430	812189	812885	813529
12	814130	814695	815229	815737	816232	816687	817135	817561	817969	818360
13	818735	819095	819440	819771	820089	820395	820689	820972	821245	821507
14	821760	822004	822239	822466	822685	822897	823102	823301	823493	823679
15	823859	824034	824204	824369	824529	824685	824837	824985	825128	825268
16	825404	825537	825667	825793	825917	826038	826156	826272	826384	826494
17	826601	826706	826809	826909	827007	827103	827197	827289	827379	827467
18	827553	827635	827717	827797	827876	827953	828028	828102	828174	828245
19	828314	828382	828448	828513	828577	828640	828701	828761	828820	828878
20	829441	829486	829045	829098	829150	829201	829251	829300	829348	829395

COMPRESSING STEEL.*

ON THE STEEL-COMPRESSING ARRANGEMENTS AT THE BARROW WORKS.

By Mr. ALFRED DAVIS, of London.

From "Engineering."

The unsoundness of steel castings, particularly in the case of ingots made by the Bessemer or Siemens-Martin process, has given manufacturers considerable trouble, and occasions much waste of material.

A good deal has been stated and written of late as to the cause of this unsoundness, which occurs principally at the upper end of the ingot; but it appears now to be pretty generally conceded that the defects proceed from two distinct causes: First, the existence of gases, generated at the point of transition from the fluid to the solid state, which are imprisoned in the form of bubbles when the surrounding metal becomes solid; and secondly, the existence of spaces formed by the natural contraction of the metal in cooling, by reason of the outer skin first becoming solid and refusing to follow up the interior portion of the ingot, which subsequently cools, and consequently occupies a smaller space.

Various systems, designed to cure this evil, have already been discussed before this Institution. The system, which is illustrated by the accompanying diagrams and models, namely, that of compressing fluid steel by the direct application of high-pressure steam, has recently been adopted by the Barrow Hematite Steel works, and by Messrs. Bolckow, Vaughan & Co., and has the merit of simplicity combined with efficiency. The arrangements adopted for the purpose are foundered upon those used by Mr. H. R. Jones, of the Edgar Thomson Steel Works, Pittsburgh, U.S., where the system has been worked for some years.

The exact plan in operation at the Edgar Thomson Steel Works is shown by the model (see *Engineering*, vol. xxviii., pages 84 and 85).

A high-pressure steam boiler is provided, and communicates with a receiver, which is attached to the side of the ingot crane, and which is furnished with a row of cocks corresponding with the number of ingot moulds. From these cocks strong india-rubber pipes convey the steam to the ingot moulds, which are arranged in the arc of a circle round the ladle crane. The metal from the ladle is poured through a loose pouring cup, which rests on a conical seat at the top of the ingot mould. As soon as the pouring is finished, this cup is removed, and a lid, having the steam pipe ready coupled to it, is placed on the top of the mould, and secured to it by a steel cotter. The cock on the receiver is then opened, and the steam allowed to act upon the metal until it has completely set. The result of this pressure is to make the ingot sensibly shorter than when cast in the ordinary manner, the difference, according to experiments, made at the Edgar Thomson Works, being from 1½ inches to 2 inches in a 5 ft. or 6 ft. ingot. The ingots when cold are perfectly level at the top, and there is no porous heads requiring to be cut off.

The arrangements adopted by the Barrow Steel Company differ somewhat from those in operation at the Edgar Thomson Works. These arrangements require only a very brief explanation.

The ingot moulds, which are of similar construction to those used by the Edgar Thomson Company, are placed in a row, within a dock or siding, the center line of which runs to the center of the pit. The metal flows from the ladle into a trough mounted upon wheels, and provided with runners at points corresponding with the centers of the ingot moulds when the trough is in position. This trough runs upon rails, placed on either side of the row of ingot moulds, and can readily be removed after the moulds are charged. Each mould is provided with a steam-tight cover, having a wrought-

* Paper read before the Mechanical Engineers, at Barrow.

iron pipe attached to it, furnished with a stop-cock. This pipe communicates at right angles with the main steam pipe, which runs parallel with the side of the dock. The junction of the branch steam pipes with the main is formed by means of a cast-iron sleeve-piece, with stuffing-boxes, to enable the covers, with their respective cocks and pipes, to be thrown back out of the way when not in use.

The boiler for suppling the steam has been constructed by Messrs. Daniel Adamson & Co. It is 3 ft. 6 inches in diameter and 9 ft. high, and is intended to be worked at a pressure of 200 lbs. per square inch.

An arrangement shown in the diagrams has not yet been put in practice; but the author believes that it has some advantages over other plans, and that it will prove an efficient method of applying the steam. The ingot moulds are fixed in position in the same manner as at the Edgar Thomson Works, but the method of securing the bottom joint of the mould is somewhat different. In one form of joint suitable for both the lid and base of the mould, V-shaped grooves are turned in the faces of the metal, care being taken that the diameters of the two grooves forming the joint are exactly equal. A ring of soft copper wire is then inserted and the two parts well keyed up with cotters, as before described.

The main pipe for supplying the steam follows the curve of the pit, about 12 in. from the side, and 18 in. below the surface of the ground. The branch steam pipe is of copper, coiled to give elasticity, and has at one end the lid of the mould, and at the other a stop-valve. The stop-valve is attached to a hollow sleeve, revolving on the main steam pipe, and is kept tight by means of stuffing-boxes. When not in use, the copper coil, lid, and coupling can be thrown back, and fall into a pit made for the purpose. This pit is covered over with an iron plate hinged at one side. No doubt other plans for applying steam pressure could be suggested, and various modifications will be necessary to suit different conditions of working.

At the Cambria Steel Works, in Pennsylvania, an attempt was made to inject water through the cover of the ingot mould, after the metal had been poured. The heat of the molten steel, of course, generated steam, which acted as a compressing medium; a safety valve being provided and loaded to the pressure required. The disadvantages of this system, as compared with that now described, are sufficiently obvious; the complication of parts and the danger from explosions being very great.

The results obtained by the process of casting ingots under steam compression are highly satisfactory. Not merely is the ingot perfectly sound, but the action of the steam is such as to enable the men to work it earlier and in a hotter state than with the ordinary method, so that there is an appreciable increase in the output. The presence of the steam also acts beneficially on the sides of the mould, and causes it to last longer.

The pressure necessary to produce a perfectly sound ingot will depend upon the quality of steel to which it is applied. At the Edgar Thomson Works it is found that for ordinary rail metal 100 lbs. per square inch is sufficient. But for milder steel a higher pressure is needed; and since experience has proved that steam is readily dealt with at very high pressures, there does not appear to be any reason why 1,000 lbs. or 1,500 lbs. per square inch should not be applied if required. It is only a question of giving sufficient strength to those parts which are exposed to the pressure. As a matter of fact, the boilers designed by Mr. Loftus Perkins will carry a steam pressure of 2,000 lbs. per square inch with perfect safety. The question of making tight joints between the ingot moulds and covers with such high pressures is one of considerable importance; but there are several ways in which this difficulty may be overcome. In using steam at a very high pressure, the size of the supply pipe may be considerably reduced, and the mode of attachment greatly simplified; and since the amount of steam used is inconsiderable, the size of the boiler would be correspondingly small. As an alternative, in cases where high pressures are needed for the consolidation of fluid metals, the author proposes the use of compressed air. With this system a pressure up to 1,500 lbs. or 2,000 lbs. per square inch may be obtained without danger or difficulty, as is completely demonstrated by the topedo

practice at Woolwich, and by the experiments carried out by Colonel Beaumont, in connection with the use of compressed air for tramway locomotion.

The advantages of an elastic compressing medium in the consolidation of fluid metals, as compared with the hydraulic process, scarcely need to be dwelt upon. In applying hydraulic pressure a rigid piston is necessary; and the outer portions of the cooling mass (which are the first to set) must be crushed down, before the interior portions, which are still liquid, are reached by the pressure. A considerable amount of power is wasted in consequence. In addition, the fluid metal is forced against the sides of the mould, and in a contrary direction to that which it naturally follows in the operation of cooling. With steam or compressed air the operation is reversed; as soon as contraction commences, the entire ingot is surrounded by a uniform pressure, which continually follows up the natural contraction of the mass.

In conclusion, the author would suggest that the principle of elastic pressure, in connection with the consolidation of fluid metals, although at present applied to Bessemer ingots only, is well worth the consideration of those interested in the manufacture of all kinds of steel and iron castings, and particularly of heavy guns.

ON THE PRESERVATION OF BOILERS.

By Rear-Admiral C. MURRAY AYNSLEY, C. B.

From the Journal of the Royal United Service Institution.

THE subject of the paper that I have the honor to read to-day is of so much importance not only to those afloat, but also to the thousands on shore who use steam power, that I much wish some one better versed in the art of clearly laying facts and opinions before an audience (a power that I on this my first appearance cannot expect to possess) was in my place now.

The information I intend to lay before you was chiefly acquired while serving on the late Admiralty Boiler Committee, which was directed, as pointed out in their Lordships' letter of the 5th June, 1874, to visit the dockyards and principal seaports to, as far as possible, take evidence of witnesses conversant with the subject, examine into the construction and mode of working boilers both in the Royal Navy and in the mercantile marine, take into consideration the properties and qualities of materials used in their construction, and consider fully in what way surface condensation has affected their durability, and what measures are to be taken in the future for their preservation.

To carry out these comprehensive instructions it was necessary to visit not only the Royal Dockyards, but also the great seaports and manufacturing towns of the country where, although through the courtesy and goodwill of the gentlemen we met every information in their power was freely afforded us, we found that nothing definite was known on the subject, and that to render our report of any value we required, for foundation, a comprehensive and extended series of experiments, to be carried out on a small scale at first, but eventually having the results verified by the working of new and other boilers both on board sea-going vessels and on land.

Although in the course of the afternoon I have to allude to other types of boilers, I shall assume that for marine purposes the circular tubular boiler carryfng a pressure of from 50 to 200 lbs., and working surface condensation engines, is the type of the future.

As our inquiry proceeded, we saw that great differences of opinion was held by engineers not only regarding the cause of decay, but also as to the effect of surface condensation, the predominant idea being that though it had in some cases caused more rapid decay than jet condensation, yet that, with proper care, surface condensation ought not to be more injurious to boilers than the old system.

When, however, we required information as to why decay occurred, then there were still more numerous and conflicting opinions as to the causes that produced it, and consequently as to any appropri-

ate measures which should be adopted for its prevention.

The causes to which corrosion was attributed were as follows:

1. Water too pure from constant condensation.
2. Fatty acids from oils used for internal lubrication, &c
3. Quality of the iron used.
4 Particles of copper carried in by feed.
5. Galvanic action between boiler and condenser.
6. The use of copper feed-pipes.
7. Bad management of boilers.
8. Copper in solution.
9. Use of copper internal pipes.
10. Chemical action.
11. Mechanical action.
12. Softening effect of distilled water upon iron.
13. Absence of air in water repeatedly condensed.
14. Too much blowing.
15. Decomposition of water, etc., etc.

With such differences of opinion there were, as would be expected, equal differences as to the method of working, and in particular as to the time water should be retained in the boilers.

The extreme difference is shown by two of the cases brought to our notice; in one the boiler was filled at Hamburgh with the river water, and went to Callao without increasing the density beyond $\frac{1}{32}$. On the return voyage the boiler was filled with sea water at Callao, and on arrival at Hamburgh the density was scarcely $\frac{2}{32}$. The total time under steam on the two runs being 109 days, no change of water taking place at sea. In the other case, besides filling the boilers no less than five times in 38 days, the quantity of water blown out was as much as 84″ per diem, the density being from 16° to a maximum of 16°.

We found fresh water frequently used for filling boilers when starting on a voyage. Sometimes the boiler was refilled at short intervals, all the water being changed; in other cases more or less of the water was blown out during short stays in harbor, no change taking place at sea; again, the boiler being filled in harbor, the waste was made up at sea either with fresh water carried in tanks, or in the double bottom, or from the sea.

Mineral oils were commonly used for internal lubrication in preference to those of animal or vegetable origin.

I will now, in order that you may be better able to appreciate the conditions of working which either insure reasonable durability or contribute to the decay and corrosion which it is so necessary to avoid, place before you a few illustrations taken from the many cases which came under our notice, selecting for this purpose those simple ones which, when compared, will best exhibit the chief causes of general decay.

Amongst the exceptional types of boilers one on the tubulous system was examined by order, with a view to making a special report. It consisted of a series of tubes, the heat being applied outside, was always worked with fresh water, the waste, which was very small, being made up with distilled fresh water; certain of these tubes being selected by us were taken out and cut up for examination; when the connection was cut, although the boiler had not had steam up for some time, the air was heard rushing in, showing that when not in use a vacuum was maintained in them, and on being cut open, a burr, as perfect as when the tube was fitted twelve years before, was found where one of the smaller tubes was screwed into the larger one. This boiler was worked at a very high pressure, and its good condition is, I believe, attributable to the non-admission of air in this system of working.

Some Lancashire boilers at Oldham may also be instanced as examples of great durability; we saw one that had been just opened to have the usual thorough overhaul at the end of five years. On these occasions the front plate is taken off, and the whole of the interior taken out. The iron tubes were as perfect as when they left the makers, and after they had been cleaned in a lathe would be returned into store for re-issue. We saw some that were being placed in the boiler, many of them re-issues with the bloom on as perfect as if new; and judging from what we saw, as also from what we were told, there was no reason why some of these taken out might not have been ten years at work. The water used in these boilers passes through a feed-heater, and is much contaminated by sewage; it requires to be

filtered from the amount of solid matter in it, so much so that a few years ago the smell was so offensive that clean water was substituted, but as in a short time it was found that the boilers were suffering from corrosion the use of the dirty water was re-introduced. At these works a tea made from a substance from Finland was used as a boiler fluid, but I believe that the feed-heating, combined with the use of water having therein a large amount of organic matter, was the cause of the good result.

Another case of good condition, resulting partly from the presence of sewage and organic matter in the water, was found in the boilers of boats in the port of Bristol; all showed well, and there was very little corrosion for the time that they had been at work. In several of these boats the condensers were fitted outside under the run, and in this plan there was so little air to deal with, that no air-pumps were required.

In another line of steamships occupied in a coasting trade and making short voyages, it was usual to keep the boilers full for six weeks, and to avoid blowing off during that time, when in harbor closing all valves, etc., and keeping a vacuum; this method of working resulted in a very good condition of the boilers at the time of our inspection.

The cases of rapid decay which were brought to our notice were, as may be imagined (excluding those in the Royal Navy), of less frequent occurrence than those of a contrary character. But amongst those that came before us, I will mention that when surface condensation was first re-introduced into marine engines one large steamship company had some engines fitted so that the air-pumps also did the duty of feed-pumps. The boilers were filled with fresh water, and any waste was made up with distilled sea water from a boiler set apart for that purpose. These boilers went with great rapidity; in one case being seriously pitted after from ten to eleven days' steaming; in other cases, after steaming from 8,000 to 10,000 miles, the boilers were in such a bad condition that the system of working was changed, feed-pumps being added at the same time, by which means the rapid decay was stopped, and the boilers were given an extra life. The benefit derived was attributed to the change of system, but it is more than probable that the addition of feed-pumps, and thereby avoiding the introduction of so much air, contributed in a much greater degree to this improvement.

We had it also in evidence that the most rapid corrosion, known to a gentleman of special knowledge on the subject, was not in boilers used for steam, but for boiling water used for clothes, etc., these going much more rapidly than in those fed with the same water, and used as boilers for engine purposes.

A very instructive illustration of the corrosion to which iron is liable when the action is reduced to its simplest form, was afforded in the condition of some of the steam pipes forming part of the system used for heating the Houses of Parliament. The water from which steam is raised comes from the deep well in Trafalgar Square, and while the boilers themselves are practically free from corrosion, some of the wrought iron pipes which convey the steam many hundred feet away suffer from oxidation, in some cases to such an extent as to cause perforation of the tube. So that the only conditions which are available for explaining the corrosion in this case are steam (partly condensed, of course,) and air.

In some cases the water supplied to boilers is for economical purposes passed through feed-heaters, and we always found that the corrosive action was expended upon these feed-heaters, thereby relieving the boilers of the corrosion which they would otherwise have suffered. When feed-heaters were first introduced they were made of wrought iron, but in consequence of their rapid decay it was found advisable to substitute those made of cast iron, as being less vulnerable to corrosive action.

Experimental confirmation of some of the different conditions involved in cases of durability or decay were obtained by experiments conducted at the ordinary temperature and pressure; they were on a very small scale, but will be sufficient for the present purpose. Strips of polished boiler plate from Yorkshire iron being immersed in sea water or distilled water with or without access of air:

Bottle No. 1 contained distilled water, the upper end of the strip being just

covered by the water, the mouth of the bottle was incompletely closed by a cork.

Bottle No. 2 contained distilled water, which was boiled in the bottle to expel air, a similar strip to that in No. 1 was then introduced, and the water again boiled under the air-pump at a lower temperature to insure the complete expulsion of air, some mineral oil was then poured in, and the bottle well corked and waxed over.

Bottle No. 3 contained sea-water and a strip of iron, the other conditions being exactly similar to No. 1.

Bottle No. 4 contained sea-water, and was otherwise arranged exactly as No. 2.

These bottles, with some others which I shall presently describe, remained in the Committee Room at the Admiralty for two months.

Oxidation commenced immediately in bottles 1 and 3, the water becoming turbid from the presence of oxide of iron (rust), which formed continuously until it had collected at the bottom and sides of the bottle in considerable quantity. At the end of the period, the strips were withdrawn, cleaned and weighed; they had lost respectively in grains per square foot per ten days:

No. 1, distilled water..... 8.27
No. 3, sea-water..... 5.76

The strips in bottles 2 and 4, with the exception of a slight tarnish, remained as they were put in; there was no oxidation, the water being quite clear.

Now you will be in a position to understand why it is so desirable to protect boilers not only when under steam, but also when out of use, from access of air; and by comparing the known conditions under which oxidation took place, or was prevented altogether in the bottles, with the conditions in the working of boilers, examples of which I have instanced, you will readily see why there should be decay in some cases and durability in others.

We found that in some ships the remedy adopted was the substitution of iron for all the copper pipes connected with the boilers, and in one case iron was used even for the steam pipe. In another case, air was pumped into the boilers, and this remedy has been gravely recommended by officials, although not carried out by the principals.

Washing the interior of the boilers with cement was a practice of some firms and with very satisfactory results. It was, I know, tried some years ago in the Navy, but not approved of, probably because it was laid on too thick, and the use of freshly burned cement not insisted upon. In one firm the superintending engineer was in the habit of having a quantity of mineral oil introduced the last thing before closing.

A curious remedy for corrosion in land boilers common in Lancashire consisted in putting a dead pig into a boiler that showed signs of pitting, and the engineers in some few steamers used to go on shore with a sack, in which any unfortunate cats, etc., were collected for a similar purpose. A story is related that an engineer of a ship in China told the ship boatman to bring off some dogs or cats for the boilers, but the man answered him that they were worth too much money, though if a dead Chinese would do he could find plenty. The origin of this custom is not known, but the introduction of organic matter is doubtless beneficial, when used for the purpose of preventing corrosion by the oxygen contained in air brought into boilers with the feed. Among the remedies for corrosion in boilers I might mention some which in many cases are applied with useful effect, such as an alkaline solution of organic matter, which acts (especially under pressure) in a similar manner to that last alluded to in the Lancashire remedy for pitting.

A common remedy for supposed acidity of the water in boilers, or in order to neutralize the effect of fatty acids, is found in the use of soda, usually in the state of carbonate. In some of the boiler compositions or fluids, usually of a proprietary nature, alkali and organic matter are found mixed together.

Among the remedies for corrosion the use of zinc was strongly advocated by some marine engineers, while others did not attribute any real advantage to it, in some cases even discontinuing its use. The contradictory opinions as to its value were plainly due to want of knowledge of the principles involved when the electro-chemical relations of two metals immersed in sea-water had to be considered, and in the few cases where a decided advantage could be traced to the zinc there can be no doubt

that metallic continuity, which is absolutely essential to success, had been accidentally effected.

The common method of using the zinc was to suspend it by means of a hook from one of the stays, sometimes under water, sometimes in the steam space, but in a Liverpool line of steamers, in consequence of the slabs of zinc coming down before the zinc was consumed, clip hooks were adopted; on arrival in port after each run the boilers and stays were carefully cleaned, and the wasted zinc plates replaced; now to clean the boilers thoroughly the zinc had to be removed, consequently not only was any replaced zinc put into the boilers at the last moment before closing, but many of the good slabs taken down for convenience while the boiler was being cleaned were replaced when the new was put in. By this arrangement a large proportion of the zinc would be, unintentionally it may be, in metallic connection with the boiler surfaces, and in this company all the engineers declared that zinc was of great value in preventing the corrosion of their boilers.

I have now to consider the means which have been adopted for preventing corrosion in empty boilers.

This condition has in former years been one of the chief causes of decay to the boilers of ships in the Royal Navy, because iron rusts or oxidizes most rapidly when exposed in a moist state to free access of air. Until within a comparatively recent date, the treatment of an empty boiler consisted in drying it by means of bogie fires, and if a condition of absolute dryness could have been effected during the whole time in which the boiler was open, the decay would doubtless have been diminished, but considering the nature of the surfaces, and the shape of the boilers so treated, there must have been an amount of decay which is avoided by the present methods of treating boilers out of use. The precautions against decay now adopted are:

1st. What may be called the dry method consists in drying the boiler in the old way; then pans filled with well-burned lime are placed in several parts of the interior, and lastly, before closing up, a quantity of ignited charcoal or coal is introduced, in order to withdraw as much of the oxygen as possible from the air shut up in the boiler; to insure the success of this method the sea cocks must be perfectly tight.

2d. By the wet method of preservation, the boilers are filled quite full with water up to the safety valves, the water being rendered alkaline by the addition of either lime or soda.

3d. The oil process used in the case of the gunboats hauled up on the slip at Haslar; oil being run into the boiler until full, and then pressure applied and kept on for a day, is so distributed over the whole of the interior, that when run off, a film is left, which dries and protects the interior surfaces from decay; here, however, the boilers are new.

In the mercantile marine, where boilers are seldom out of use except for short intervals, chiefly during repairs, the precautions I have mentioned are unnecessary, and in this comparative freedom from exposure lies their immunity from the decay which we have been considering.

As a precaution against the accidental admission of air to the interior of boilers out of use, it is advisable to render the water alkaline either by the addition of lime or soda; and for the purpose of illustrating these conditions, strips of iron corresponding in every particular with those previously mentioned, were immersed in bottles containing—

1. Lime water, solution of caustic lime in distilled water.
2. Sea water, rendered alkaline by a limited quantity of carbonate of soda.
3. Sea water with an excess of carbonate of soda.

In these cases corrosion was entirely prevented so long as the alkaline condition was maintained, and at the end of twelve months the strips were quite bright, as when introduced.

Another series, in which there was free admission of air to sea water of different densities, showed the following losses:

	Grains.	
In sea water of $\frac{1.0}{1.2}$ densities, loss..	2.81	
" $\frac{1.0}{1.2}$ " ..	3.13	per
" $\frac{1.0}{1.2}$ " ..	6.52	square
" $\frac{1.0}{1.2}$ " ..	6.79	foot in
Fresh water from main.....	8.33	ten
Distilled	6.17	days.
Distilled from sea water.....	6.38	

Those figures which represent the loss

in sea water of different densities are interesting, in so far that sea water of high density appears to possess less power of absorbing and transferring air to iron than the water containing an ordinary amount of salt.

I shall in this place only notice seven of our experiments at Devonport. Three of these consisted in working or treating boilers as we had previously proposed, viz.:

1. To wash the interior of boilers with a coating of Portland cement.

2. To cover the interior surfaces of a boiler with mineral oil.

3. To retain the same water in a boiler for as lengthened a period as possible, so long as the density did not rise beyond $\frac{6}{32}$.

4. To ascertain the protective value of different qualities of zinc.

5. To determine whether zinc lost any portion of its efficiency through the loss of connection by riveting the plates together.

6. To compare the action of the water in jet and surface condensers upon iron.

7. To illustrate the corrosive action of feed-water, and the diminished action of the same water after it had passed through the heater upon the boiler.

1. A. The interior surfaces of a land boiler were thoroughly cleaned and washed with fresh Portland cement; this boiler was inspected from time to time; the adhesion continued always perfect and gave full protection to the surfaces, no spots of oxide being visible; and however much the cement might appear to be worn off, a scratch with a knife always showed that some of the cement remained.

B. One of the old rectangular boilers in the tug "Perseverance" (surface condenser) was, after some months' wear, cleaned as far as the nature of the boilers would admit, and washed with cement; the adhesion was very good, and, although no zinc was used, there was but little sign of decay at the end of two years.

C. Several boilers in course of construction were also treated in the same manner. First, before the heating parts were put in and again afterwards—the boilers were kept open for some months in the boiler shed before the mountings were attached. There was no sign of rusting, and the cement, if rubbed with the hand, was quite dry and dusty.

2. The interior of the other boiler of "Perseverance" was painted with mineral oil. It stood the work perfectly, and, after six months' steaming, the surfaces were quite oily. A similar experiment in the "Assistance" troopship failed, but the difference of pressure and consequent temperature (the "Perseverence" carrying only 30 lbs., while the "Assistance" carried 50 lbs.) will fully account for this.

3. The "Perseverance" retained the same water in her boilers for over six months, but in consequence of a freshet in the harbor at the time she ran them up, more solid matter was introduced than usual, and, as the quantity was gradually increased, it became necessary to empty the boilers, not because the density was too high, but on account of the priming caused by the solid matter. At the commencement of this experiment the density of the water in the boiler was 9°, and at the end of six months it had only risen 24°, or about $\frac{2\frac{1}{2}}{32}$. I wish to draw special attention to this experiment, even in its limited form, because it disposes of a notion which till within a recent period was extremely prevalent, viz., that it was necessary for the welfare of a boiler to constantly change some of the water; the reasons which were assigned for this practice being various, though mostly illogical. In the days of jet condensers, the rapid increase of density was a reason sufficiently obvious; but when surface condensers were introduced the density no longer increased with the same rapidity, and yet the practice continued, though with tight condenser tubes the water returned to the boiler from the hot well should contain scarcely any solid matter.

Possibly the old custom and the general idea that it was necessary to blow off at $2\frac{1}{2}$ densities, together with the direction on many salinometers to do so at that density, may have caused a continuance of the practice, but a little consideration will show that it is a positive disadvantage; for example:

1st. Hot water is blown out and cold water substituted; this means a loss of fuel.

2d. Water is blown out which has parted with some of its sulphate of lime, and water is substituted which contains its normal quantity, thereby constantly adding to the amount of scale upon the heating surfaces; this also means a greater expenditure of fuel, and an unnecessary opening up of the boiler in order to scale it.

3d. Water is blown out which, by boiling, has been freed from air, and water is substituted containing its usual quantity of dissolved air which contributes to the decay of the boiler.

Had it not been for the accumulation of mud in the boiler of the "Perseverance" the same water might have been retained for a much longer period, or until the density had risen to double what it was when the accidental necessity occurred for emptying.

I have specially dwelt upon this point because, even at the present day there are marine engineers who tenaciously adhere to the traditions of the past, and who consequently incur all the evils which are inseparable from an unscientific method of working.

At the same dockyard the "Trusty" tug, with jet condensers, only required to change the water six times in over five months.

A tubular marine boiler working a land engine in the dockyard retained the same water for six months, and was in an excellent condition when opened, and at the end of eighteen months' work file marks were still visible.

4. The zinc slabs in the boiler of the "Trusty" were of three qualities, viz., zinc "bottoms," ordinary commercial zinc, and a third of extra good quality; the results being that the plates lost in grains per square foot per ten days:

With best zinc	2.02
" commercial	15.14
" bottoms	18.08

5. Slabs of zinc were bolted on to a bright surface of two iron bars, each being in two parts; in one case bolted together through drilled holes with turned bolts; in the other riveted in the ordinary manner. The losses per square foot in ten days were as follows:

Bolted	33.15
Riveted	36.16

6. Here by some error the piece intended to have been in condenser of "Trusty" was placed in the passage to the hot well. The losses were per square foot in ten days:

Condenser of "Perseverance"	133.67
Hot well of "Trusty"	802.07

7. Plates were placed in four positions, two in buckets plunged in the feed heater, one being filled with water from the main, another with water from the condenser, a third in feed heater fed with overflow from the two buckets, and a fourth in the boiler. The losses were per square foot in ten days:

	Grains.
The plate in bucket filled from the main, lost	25.16
" " condenser	38.37
" " feed heater	40.52
" " boiler	1.90

but the second and third of these plates were, after a considerable time had elapsed, found to have been protected with oil showing no corrosion; if this be taken into account, the loss will be—

From main	25.16
" condenser	79.87
In feed heater	84.37
" boiler	1.90

Two series of pieces cut from the same plates of iron and steel showed the following average loss during ten days:

In "Perseverance" boiler, steel	22.63
" " iron	17.92
In feed heater, steel	78.62
" iron	71.43

The former being salt and the latter fresh water.

I now proceed to describe a more extended series of experiments called in our report the Ocean Plate Experiments, and which unfortunately at the time of the dissolution of the Committee in March, 1878, were not in a sufficiently advanced state for us to do more than allude to them. The object of this series of experiments was to determine what method of practical working at sea caused the least decay, and at the same time to ascertain whether, as in the Sheerness experiments, there was a difference in the amount of corrosion suffered by different varieties of "steel" as compared with iron when subjected to the same conditions.

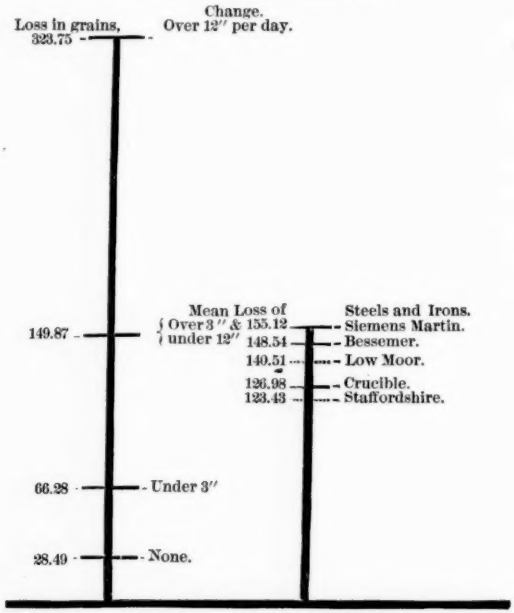
A number of sets of plates, including in each set three of steel and two of iron, were arranged in the same order, and in such a manner as not to interfere

with each other. The plates had bright but not polished surfaces, and were all of the same dimensions, viz.: 4 inches square and $\frac{3}{8}$th in. in thickness. An insulated set of these plates was suspended in such a manner as to be uninfluenced by any condition except that of the water, in one of the boilers of men-of-war on the Mediterranean, West Indian, Pacific, Australian, China, Brazil, Cape and East Indian Stations, troop ships on home and foreign service, tugs in the home ports, and merchant vessels belonging to no less than forty-five of the principal steamshipcompanies trading to every part of the globe. A blank form was supplied with each set of plates, in order that the chief engineers might fill in all the particulars with respect to the conditions of working, and other circumstances, during the continuance of the experiment.

We anticipated that in the collective results to be obtained from so many sources, we should be in the possession of facts which would either modify or corroborate the experience which we had already acquired; and although I am sorry that I have only been able to avail myself of forty-two sets in the preparation of this paper, it very fortunately happens that amongst them there is nearly an equal number which represent the principal methods of working.

The loss is given in grains per square foot for each ten days that plates were in boiler.

OCEAN PLATE EXPERIMENTS.



The loss is given in grains per square foot for each ten days plates were in boiler.

In some few cases, however, certain sets are not available for all purposes; thus, should a boiler worked on the principle of no blowing or change of water prime badly (as in the case of the "Perseverance" before mentioned), it cannot be compared with others as to change of water, but it is still trustworthy as to the comparative corrosion of steel and iron, and also for mean corrosion.

I will first draw your attention to those results which illustrate the effects of change of water, and for this

purpose I shall divide them into four groups:

1st. Those that do not change any water at sea.

2d. Those that change 3″ and under every twenty-four hours.

3d. Those that change between 3″ and 12″ every twenty-four hours.

4th. Those that change over 12″ every twenty-four hours.

It would have been instructive to subdivide these into boilers filling with sea water and fresh water; boilers making up waste with sea water or with fresh water carried in tanks, etc.; also to distinguish between them according to the intervals of changing all or nearly all the water, but the number of results at my disposal will not permit of this.

In the 1st group of 10 sets, the mean loss was 66.49 grains per sq. foot in ten days.

In the 2d group of 9 sets, the mean loss was 26.49 grains per sq. ft. in ten days.

In the 3d group of 7 sets, the mean loss was 149.87 grains per sq. ft. in ten days.

In the 4th group of 6 sets, the mean loss was 323.75 grains per sq. ft. in ten days.

And among boilers in the first group, the plates in those which are emptied at the shortest intervals suffer most.

Now if we read these figures simply in connection with one condition of working, viz., change of waters, you will see how they confirm what I said just now with regard to its disadvantage in connection with the case of the "Perseverance," and that of boilers generally.

In what follows I have not divided the sets of plates into groups, but (except for some special purpose of illustration) include all. The effect of different lubricants in connection with corrosion is when mineral oil is compared with vegetable oil; the losses are:

Mineral	134.81
Vegetable	134.87

But though by this it would appear that the influence of lubricants has been much over-estimated, it is hardly a just view, as all the fourth group use mineral oils; excluding these, the numbers are:

Mineral oils	74.70
Vegetable oils	134.87

thus showing a considerable advantage in the use of mineral oils; but it must be stated that as only four used vegetable oils, the number is too small to give trustworthy data.

We next come to the comparative merits of steel and iron so far as corrosion is concerned, and with the following results (see diagram):

Mean loss of crucible	126.98	
" Bessemer	148.54	Steel.
" Siemens-Martin	155.12	
" Staffordshire	123.43	iron.
" Lowmoor	140.51	

	Of steel.	Of iron.
Group 1st, mean loss	28.04	26.04
" 2d, " "	60.05	60.22
" 3d, " "	149.49	146.34
" 4th, " "	328.46	314.10
Mean with surface condensers,	115.67	109.44
Mean with jet condensers	179.42	119.38

A further illustration of the effect of change of water may be given in the following results, which were obtained in connection with the first table, by comparing the use of fresh or land water with sea water:

Group 1st	F. 28.37	S. 20.51
" 2d	" 48.77	" 101.70
" 3d	" 73.28	" 166.38

This shows that while the boiler is what I consider properly worked, *i. e.*, no change taking place, the advantage is in favor of the sea water, but when the water is changed, the fresh water has the advantage. It must, however, be borne in mind that no zinc was in connection with the plates.

The advantage in using fresh water in sea-going ships will be found in the fact that by filling the boilers with it when opportunity offers at starting on a voyage, the necessity for change on account of increased density is very much diminished, if not altogether avoided.

Two sets of these plates were tested in a steamer that filled the boiler at short intervals with sea or river water, according to the port she was in, but never changed any at sea. One of these sets was suspended in the only feed heater attached to marine engines we were then aware of, the other in the boiler fed with water that had passed through the heater. The respective losses were in grains per square foot per ten days:

In boiler	16.53
" feed water	93.23

that in a steamer belonging to the same company, running between the same

ports, and worked in a similar way, being 37.44.

Considering the title of my paper, viz., "The Preservation of Boilers," I might have introduced some of the minor causes which are supposed to contribute to decay, such as the fatty acids resulting from the use of lubricants having an animal or vegetable origin; the accidental damages caused by other metals, such as copper, brass or lead;* the oxidation produced by allowing water to lie at the bottom of open boilers; mechanical and solvent action resulting in the detachment of scale or in preventing its deposit, such as the local action of the feed, and so on. Some of these causes which have been assigned for corrosion by marine engineers may contribute in a small degree to the decay of boilers, but many have nothing to do with it, and yet decay is attributed to them, instead of the real cause.

It must be remembered that a boiler is a closed vessel, to which you can admit, or from which you can exclude, what you please, with little exception, and also that what may be detrimental to an unprotected plate of iron in the open sea may be absent or comparatively harmless to the same plate when it forms part of a boiler, because the conditions as to the power to corrode and of the surface to be corroded may be totally different in the two cases.

I would not for a moment discourage all advisable precautions with regard to the mechanical safety of steam boilers, nor attempt to undervalue the inspection which doubtless has often saved many valuable lives; but the constant opening up, more especially of marine boilers, appears on reflection to be un necessary. If it be urged that opening up is unavoidable for the purpose of scaling, then it may be answered that the accumulation of scale is preventible by a system of working which keeps it out, and it must be possible, by means of mechanical appliances, to exclude most of the dirt which gains access to a greater or less extent. So far as the scale deposited from clean sea water is concerned, there can be no hesitation in admitting that a limited amount is an advantage, not only because when well deposited it protects the boiler surfaces, but because it offers a better and rougher surface for ebullition than a smooth boiler plate. It is the practice in some ships to carry a supply of fresh water on board to make up waste. This, however, would be, for many reasons, impracticable in a man-of-war, and I will here relate, for the information of shore engineers, what happened to me while in command of Her Majesty's ship "Monarch."

We were off the south coast of Ireland, with ample coal to go anywhere, but as the ship had to try rate of sailing with other ships, I deemed it advisable to run up two of the compartments in the double bottom, next to where the coal had been chiefly taken from. That same day we had to try rate of sailing, and though we had not more than 180 tons of water in the two compartments, which we thought were completely full, the bracket framing kept the water from close filling them, and the ship was like a log, some ships which ought to have been nowhere, beating us. We went the next day into Queenstown, and I succeeded in filling the bottom, adding about 12 tons in all; we went to sea again, and easily beat the other ships, the feeling of the ship as she went through the water being quite different from what she was on the former occasion.

Under steam this evil is less felt, but men-of-war ought to be always in a state to do their best.

I will now briefly recapitulate the treatment which should be observed for boilers during construction, and the system of working which would appear best calculated to give them durability when in use for raising steam.

1. During construction the surfaces should be protected by a wash of freshly burned Portland cement, three coats being given and repeated if necessary.

2. Zinc should be distributed in such a manner that all the surfaces below the water may be equally protected, great care being taken as to metallic continuity.

3. After the proper amount of scale has been obtained upon the surfaces in the presence of zinc, there should be no blowing off, and that if practicable the waste should be made up by distilled sea water.

4. There should be a true auxiliary

*One large company has copper tube plates, and with no injury to the boilers.

boiler, not only to distil for drinking, cooking and bathing purposes, but also that, by means of a steam pipe to the condenser, it should at a low pressure make up the waste in the main boilers.

5. That the boilers should always be kept full, and steam be got up to expel the air on first filling; if likely to be soon wanted, they should then be closed with the water at the working level under a vacuum, but if not shortly required, they should be kept quite full.

6. That boilers once filled should never be opened, or air permitted to gain access, except for repair, until it is necessary to replace the zinc, the necessary time being determined by experiments, and that with a view of opening boilers as seldom as possible, whenever any zinc is changed, the whole of the zinc should be replaced.

7. That should from any cause the density rise, no change of water be made until it rises to 50°, or even 60°.

The necessary additional fittings to boilers would be a pipe from the lower part of the safety valve to condenser, so as to avoid the waste of steam, and a provision for free egress of air provided for, between the feed pump and the boiler.

"THE RIVER NILE."

By BENJAMIN BAKER, M. Inst. C. E.

From Proceedings of the Institution of Civil Engineers.

THIS paper may be considered as supplementary to, and where conflicting as in substitution of, the article on the same subject in Mr. Beardmore's "Manual of Hydrology." It is based chiefly upon Egyptian Government documents, the returns of Mr. Fowler's assistant engineers in Egypt, and the Author's own observations.

The height of low Nile above the mean sea level at Alexandria has been ascertained by leveling at the following places:

	Height in Feet.	Distance in Miles.
Rosetta Mouth	*	..
Kafr-el-Zaiat	4.3	36
Grand Barrage	33.5	110
Cairo	39.5	126
Benisouef	75	200
Minieh	107	285
Siout	146	380
"First Cataract" (below)	303	714
" " (above)	319	716
Wady Halfa	392	964
Hannek	659	1,205
Guerendid	745	1,418
Oum Deras	907	1,468
El Kab	935	1,490
Junction of the Atbara	1,148	1,671
Shendy	1,165	1,756
Khartoum, junction with the Blue Nile	1,212	1,870

At high Nile the surface slope of the river averages about 5 inches per mile, except at the cataracts or rapids. The Grand Barrage is situated at the apex of the Delta, where the river diverges into two branches. For a distance of 30 miles below the barrage the surface slope of the western or Rosetta branch is $5\frac{1}{2}$ inches per mile; and of the eastern or Damietta branch, $4\frac{1}{2}$ inches. The latter branch is 13 miles longer than the former, and, as will be shown hereafter, by far the larger volume of water is conveyed down the shorter branch.

The "first cataract" of the Nile is situated at Assouan. Between Assouan and Wady Halfa the river is navigable, but there are fourteen more or less serious obstructions, such as rocks in the channel, and shifting sands. Between Wady Halfa and Oum Deras there are eighteen cataracts; beyond that to El Kab a continuous series of rapids, and from thence to Shendy three more cataracts, after which the Nile becomes navigable as far as Khartoum.

In the portions of the river where equilibrium is established between the velocity of the current and the stability of bed, the sectional areas, both at low and high Nile, are remarkably constant at widely distant points. Thus near Kohé, about 1,200 miles up the river, the area at low Nile is 14,000 square feet, and at high Nile, 71,000 square feet; whilst at Queremât, about 56 miles above

* The maximum known variation in the sea level is from −1.57 feet to +2.32 feet.

Cairo, the respective areas are 13,000 and 74,000 square feet; and at the barrage, 16 miles below Cairo, 12,500 and 72,000 square feet.

By far the most characteristic feature and interesting fact connected with the Nile is the singular uniformity in the date of commencement and the extent of its annual rise. The whole agricultural arrangements of the country hinge upon this, and the productions of the soil are so dependent upon the last few feet rise of the Nile, that with a rise of but 17 feet 6 inches famine is inevitable, and even of 19 feet 6 inches but too probable, whilst between 20 feet and 23 feet by the coudees gradually becoming shorter. As the height of the high Nile is not infrequently given in the *Times*, as in the Egyptian newspapers, in coudees, or pics, and kerats (of which there are 24 to the coudee), it may be useful to state that the following equation expresses approximately the corresponding height in feet above low water:

Height in feet $=1.52$. (Height in coudees $-$ 7 coudees 11 kerats.)

The Egyptian Government engineers have translated into French Arabic measurements of the high Nile occurring between 1825 and 1874, and the following are the results in feet:

1825–34	19.0	23.0	22.0	21.0	25.0	21.8	22.2	21.4	18.8	23.8
1835–44	19.4	20.4	19.0	21.0	22.0	25.2	25.0	25.2	22.0	21.6
1845–54	20.8	24.8	23.3	25.3	25.3	21.2	25.5	20.8	25.5	24.8
1855–64	20.3	25.5	21.3	21.0	20.8	25.2	26.2	23.2	26.6	19.6
1865–74	23.1	27.4	21.2	19.3	27.6	26.1	24.2	25.2	20.6	28.0

the supply of water is barely sufficient, though at 26 feet it is excessive. Beyond the latter height famine again threatens, because the salts in the soil are carried to the surface by the upward filtration of the river water, and the land becomes utterly unfit for cultivation until the salts have been washed away by a succeeding inundation. It must be observed that the surface of the land adjoining the river banks is about 17 feet above low water, and that it falls away from the river at the rate of about 5 inches per mile. Hence, with a 28-feet rise, such as occurred in 1874, the head for filtration is at least 11 feet; and although the river banks may be kept sound by the labor of a hundred thousand men, the water readily finds its way through the porous soil, and floods the land with a noxious solution of calcareous and magnesian salts and alkaline chlorides.

The height of the Nile has been recorded at Rhoda from time immemorial; but unfortunately the coudees of the nilometer are not all of the same length, so the returns have often misled European engineers. The last few feet rise of the flood are obviously of far greater importance than the first, and this fact finds expression at Rhoda

The earliest day on which the Nile commenced to rise in any of the preceding years was on the 10th of June, 1852, and the latest on the 10th of July, 1859. The earliest high Nile occurred on the 27th of August, 1868, and the latest on the 20th of October, 1872.

For some years past the daily height of the Nile has been recorded at the barrage, on a nilometer graduated to meters—a much more convenient unit than the varying coudee. The author has plotted diagrams of the heights for a series of years, and selects those for the years 1868, 1869, and 1870 as the most characteristic and interesting. To fully appreciate the identity of the phenomena exhibited each year—the first rapid rise, the slight halt, the final rise, and the relatively slow ebb to low Nile level, it is necessary to plot the diagrams on a large scale, and the original readings are therefore given to enable this to be done. As the unit of measurement and the calendar are immaterial, the author, to avoid errors in reduction, retains the metric measures and the Coptic calendar, remarking merely that the Coptic year consists of twelve months of thirty days, and a complementary month of five days, and that the first day of the year 1585 corresponds to the 11th September, 1868.

HEIGHTS OF THE NILE IN METERS, ON THE BARRAGE NILOMETER, FROM THE LOW NILE OF 1868 TO THE LOW NILE OF 1871.

COPTIC YEAR 1584.

Months.	1	3	5	7	9	11	13	15	17	19	21	23	25	27	29
Baouna	..	..	..	..	..	..	..	..	..	..	0.59	0.60	0.60	0.60	0.64
Ahbeeb	0.66	0.73	0.81	0.92	1.32	1.42	1.58	1.55	1.79	2.00	2.40	2.50	2.75	2.93	3.10
Missra	3.48	3.94	4.24	4.24	4.24	4.24	4.75	5.65	5.73	5.70	5.83	5.89	5.75	5.70	5.75
Nasi	5.75	5.63	5.58	..	..	..	..	..	..	..	..	..	..	..	..

COPTIC YEAR 1585.

Months.	1	3	5	7	9	11	13	15	17	19	21	23	25	27	29
Tout	5.56	5.52	5.48	5.48	5.48	5.48	5.58	5.55	5.55	5.52	5.50	5.48	5.40	5.35	5.33
Baba	5.30	5.15	5.05	4.95	4.90	4.79	4.75	4.70	4.60	4.38	4.28	4.24	4.20	4.12	4.05
Hatour	3.95	3.87	3.80	3.70	3.68	3.65	3.62	3.50	3.35	3.30	3.23	3.18	3.15	3.08	3.04
Kyak	3.00	2.90	2.85	2.80	2.78	2.75	2.72	2.70	2.68	2.65	2.60	2.56	2.52	2.50	2.48
Touba	2.45	2.40	2.30	2.22	2.20	2.15	2.07	2.00	1.95	1.85	1.75	1.70	1.60	1.12	1.10
Emshir	1.10	1.10	1.10	1.10	1.09	1.05	1.00	0.98	0.95	0.93	1.40	1.38	1.35	1.32	1.30
Barmahat	1.28	1.25	0.80	0.80	0.78	0.78	0.76	0.75	0.74	0.74	0.72	0.71	0.70	0.70	0.69
Barmouda	0.68	0.68	0.67	0.66	0.66	0.65	0.62	0.60	0.59	0.57	0.56	0.55	0.55	0.54	0.53
Bashams	0.52	0.51	0.50	0.49	0.48	0.48	0.47	0.46	0.45	0.45	0.45	0.44	0.44	0.42	0.47
Baouna	0.44	0.44	0.44	0.42	0.42	0.40	0.52	0.55	0.55	0.55	0.38	0.45	1.23	1.45	1.60
Ahbeeb	1.85	2.15	2.25	2.25	2.25	2.25	2.29	2.35	2.45	2.57	2.63	2.66	3.08	3.65	4.08
Missra	4.43	4.68	4.89	5.16	5.35	5.49	5.67	5.82	5.90	5.97	6.02	6.15	6.20	6.25	6.27
Nasi	6.35	6.40	6.47	..	..	..	..	..	..	..	..	..	..	..	..

COPTIC YEAR 1586.

Months.	1	3	5	7	9	11	13	15	17	19	21	23	25	27	29
Tout	6.50	6.60	6.65	6.75	6.85	6.98	7.00	7.02	7.05	7.07	7.05	7.10	7.20	7.30	7.40
Baba	7.74	7.92	7.95	7.75	7.60	7.50	7.40	7.29	7.20	7.09	7.00	6.90	6.75	6.60	6.40
Hatour	6.30	6.15	6.05	5.90	5.85	5.45	5.40	5.58	5.55	5.53	5.50	5.40	5.35	5.25	5.22
Kyak	5.10	5.03	4.90	4.83	4.72	4.62	4.50	4.37	4.25	4.13	4.00	3.90	3.82	3.80	3.80
Touba	3.75	3.73	3.79	3.67	3.65	3.63	3.60	3.58	3.57	3.55	3.51	3.47	3.40	3.30	3.15
Emshir	3.09	3.09	3.05	3.00	3.00	2.85	2.85	2.80	2.78	2.76	2.75	2.65	2.60	2.57	2.53
Barmahat	2.50	2.47	2.45	2.40	2.37	2.35	2.30	2.25	2.17	2.10	2.02	1.95	1.86	1.72	1.60
Barmouda	1.52	1.40	1.40	1.38	1.35	1.33	1.33	1.30	1.25	1.25	1.23	1.22	1.21	1.20	1.18
Bashams	1.17	1.16	1.15	1.13	1.10	0.70	0.70	0.69	0.68	0.65	0.65	0.63	0.62	0.62	0.60
Baouna	0.58	0.57	0.56	0.55	0.55	0.54	0.53	0.53	0.52	0.50	0.51	0.52	0.54	0.55	0.55
Ahbeeb	0.55	0.62	0.75	1.00	1.60	1.75	2.15	2.50	2.75	3.25	3 88	4.15	4.25	4.39	4.75
Missra	5.42	5.90	6.20	6.32	6.40	6.40	6.40	6.50	6.50	6.50	6.60	6.62	6.65	6.68	6.75
Nasi	6.80	6.80	6.82	..	..	..	..	..	..	..	..	..	..	..	..

COPTIC YEAR 1587.

Months.	1	3	5	7	9	11	13	15	17	19	21	23	25	27	29
Tout	6.88	6.95	7.10	7.25	7.25	7.31	7.32	7.30	7.25	7.23	7.23	7.25	7.25	7.30	7.37
Baba	7.45	7.53	7.55	7.48	7.43	7.40	7.41	7.42	7.33	7.27	7.17	7.09	7.00	6.85	6.85
Hatour	6.70	6.55	6.30	6.13	6.05	5.95	5.75	5.75	5.55	5.40	5.38	5.25	5.25	5.15	5.12
Kyak	5.10	5.05	4.85	4.62	4.50	4.40	4.34	4.30	4.25	4.22	4.15	4.08	4.04	4.00	3.95
Touba	3.82	3.79	3.78	3.76	3.74	3.70	3.66	3.64	3.60	3.58	3.55	3.54	3.50	3.43	3.40
Emshir	3.35	3.34	3.32	3.29	3.26	3.20	3.16	3.14	3.12	3.09	3.05	3.00	2.95	2.91	2.88
Barmahat	2.84	2.82	2.79	2.76	2.73	2.65	2.57	2.53	2.48	2.40	2.39	2.33	2.28	2.25	2.23
Barmouda	2.23	2.21	2.21	2.19	2.18	2.16	2.14	2.13	2.10	2.07	2.05	2.02	2.00	1.97	1.95
Bashams	1.90	1.83	1.80	1.70	1.65	1.58	1.57	1.54	1.45	1.32	1.25	1.15	1.10	1.00	0.73

The barrage where the preceding observations were taken, is about 16 miles below Rhoda, so a difference may be expected and will be found in the readings of the two nilometers.

The average heights of high Nile at Rhoda and at the barrage, during a series of years, are given below:

	Meters.	Feet.		Years.
Rhoda*.	6.97	=22.86	(average of	48 1824–72)
Barrage†.	6.87	=22.54	("	16 1846–61)
Barrage‡.	6.91	=22.66	("	10 1864–73)

The average heights in mèters at five-day intervals for the years 1846–61 have been tabulated by Lombardini as under:

——	5	10	15	20	25	28to31
January	2.79	2.68	2.58	2.48	2.39	2.26
February	2.18	2.07	1.96	1.83	1.72	1.65
March	1.54	1.45	1.35	1.26	1.18	1.08
April	0.99	0.94	0.87	0.81	0.74	0.69
May	0.64	0.62	0.58	0.53	0.51	0.47
June	0.44	0.48	0.48	0.48	0.66	9.76
July	0.90	1.05	1.27	1.44	2.16	3.22
August	4.15	4.87	5.57	5.76	5.87	5.97
September	6.09	6.13	6.18	6.17	6.19	6.48
October	6.60	6.55	6.51	6.37	6.21	6.22
November	5.73	4.97	4.66	4.09	4.00	3.80
December	3.61	3.42	3.25	3.19	2.97	2.90

It will be understood that the above are the average heights in a series of years, and not the heights in an average year. If it had been the latter the maximum height would have been 6.87 instead of 6.60, and the minimum 0.30 instead of 0.44, the difference being due to the overlapping of the dates of maximum and minimum heights in different years.

The system of irrigation practised in upper Egypt appreciably affects the readings on the nilometers of Rhoda and at the barrage. When the Nile has attained the height of about 3 or 4 meters, a large volume of water flows down the numerous canals having their beds at that height above low water; and when a still greater height is attained, banks are cut and the filling of the great basins of inundation causes the level of the water in the river to remain almost stationary for some days. In the same way, the drainage of these basins, after the water has stood on the land a sufficient period to deposit the fertilizing matters in suspension, causes an abnormal rise in the river.

Four measurements of the ordinary low Nile discharge at the barrage by Mr. Fowler's engineers, and by General Stone's Egyptian staff, gave the following results:

Cubic meters per second.

Low Nile discharge=355; 397; 415; 460; mean =406 cubic meters, or, say, 14,000 cubic feet per second.

Three measurements at Cairo by Linant Bey indicate the following discharges for high Niles, ranging from 7 to eight meters in height above zero:

Cubic meters per second.

High Nile discharge = 8,166; 9,469: 9,740; mean = 9,122 cubic meters, or, say, 320,000 cubic feet per second.

It has been shown that the maximum height of the Nile averages less than 7 meters, so the average maximum dis-

* 'Statistique de l'Egypte.' Cairo.
† Lombardini. 'Saggio idrologico sul Nilo.' Milan, 1865.
‡ Author's aeturns.

charge will also be less than the above. The author, after consideration of all the data, estimates the latter at 8,400 cubic meters, or say 296,000 cubic feet per second; and having reference to the preceding measurements at high and low Nile, and to measurements at intermediate levels by General Stone's staff and himself, he has deduced the following formula for the discharge of the Nile in cubic meters per second, for any height h, in meters above zero on the nilometer. As the Nile at low water is a series of pools at places, the local level of low water may vary with the same discharge, so the height h should be taken from the average readings on several nilometers.

$$Q = 200\ (h + 1)^{1.8} + 150.$$

Applying this equation to the mean heights already given, the following will be the average discharge in cubic meters per second throughout a series of years, at five-day intervals:

CUBIC METERS PER SECOND.

——	5	10	15	20	25	28to31
January....	2,351	2,237	2,136	2,037	1,950	1,828
February...	1,755	1,656	1,560	1,451	1,361	1,306
March.....	1,221	1,153	1,081	1,018	963	897
April.....	840	809	767	732	692	664
May.....	637	627	606	580	570	550
June.....	536	554	554	554	648	704
July.....	785	878	1,024	1,146	1,736	2,820
August....	3,972	4,986	6,074	6,386	6,570	6,740
September..	6,946	7,014	7,102	7,084	7,118	7,632
October....	7,850	7,760	7,686	7,436	7,154	7,172
November..	6,336	5,136	4,680	3,892	3,774	3,516
December...	3,280	2,952	2,856	2,786	2,542	2,458

For an average year the minimum discharge will be 400 cubic meters, and the maximum 8,400 cubic meters, the difference, as already explained, being due to the varying dates of the maximum and minimum discharge in different years.

From the above tabular statement, and from the analyses of Nile water by Dr. Letheby and Professor Wanklyn, the Author estimates the discharge per month of water and solids to average as follows:

——	Water in Millions of Cube Meters.	Solids in Suspension in Tons Weight	Solids in Solution in Tons Weight
January...	5,616	942,000	815,000
February..	3,715	468,000	546,000
March....	2,851	152,000	510,000
April.....	1,944	129,000	353,000
May.....	1,598	76,500	326,000
June.....	1,555	107,500	315,000
July.....	3,744	668,000	610,000
August..	15,508	23,100,000	2,570,000
September	18,532	10,100,000	3,600,000
October...	20,045	7,600,000	3,200,000
November.	11,793	4,050,000	1,765,000
December.	7,517	2,180,000	1,025,000

In an average year, therefore, the Nile conveys to the sea 49,573,000 tons of solids in suspension; 15,635,000 tons of solids in solution, and 94,418,000,000 cubic meters, or, say, tons of water. Lombardini estimated the latter at 107,828,558,000 cubic meters, but his data were imperfect.

The solids in the preceding estimate are of course assumed to be chemically dry, or the weight would be much greater. Thus, at the Cairo water works, it is found that at high Nile the solid matters deposited on the filters in the form of sludge are practically 800 parts per 100,000 of water, though Dr. Letheby's analysis indicates a maximum of 150 parts of chemically dry solids.

Large though these volumes be they would be exceeded if the measurements were taken higher up the river. Linant Bey measured the flow at Khartoum, where the White and Blue Nile join, and found the minimum and maximum flow for the year to be 297 cubic meters, and 6,044 cubic meters, in the instance of the former; and 159 cubic meters, and 6,247 cubic meters, in that of the latter. He measured also a high Nile discharge of 12,700 cubic meters at Gibil Cilcilly, near the first Cataract.* No doubt 20 or 30 per cent. of the volume of the Nile is lost between Khartoum and the barrage by evaporation and absorption.

It was stated at the commencement of this paper that by far the larger volume of water is conveyed to the sea by the Rosetta branch. This was not always so, but is a consequence of the construction of the barrage, and of the neglect

*Travaux éxécuté en Egypt. Paris, 1873.

of ordinary precautions in training the river immediately above that work. Unloss matters are managed better in the future the river will take charge of affairs itself, and sweep the Rosetta half of the barrage down stream.

The Rosetta barrage is 1,525 feet in total length, and includes sixty-one arches of 16 feet 4 inches span each. The Damietta barrage is 1,787 feet long, and has ten more arches in the water-way. At low Nile, in 1874, about 200 cubic meters per second flowed through the former, and 181 cubic meters through the latter span. A few days later the volumes had increased to 305 and 268 cubic meters, and the differences then rapidly grew wider.

In September, 1877, the Author measured the flow down the two branches of the river, and the canals having their headworks at the barrage, as follows:

	Cubic Meters.	Mean Velocity of Current.
Rosetta branch..	3,220	3.28 miles an hour.
Damietta..	1,830	1.56 " "
Menoufich canal.	230	
Behera " .	140	
Total	5,420 cubic meters per sec.	

The high Nile of 1877 was one of the lowest and most disastrous for many years. At the time of the above measurement the nilometer above the barrage indicated a height of 5.25 meters, and that below, 5.10 meters. By the formula $Q = 200\ (h + 1)^{1.8} + 150$, the volume corresponding to the former height is 5,564 cubic meters, and to the latter 5,332, the mean being 5,448, or practically the same as the measured amount.

The preceding figures, significant though they are, do not indicate the worst feature about the barrage works, namely, that the 1,830 cubic meters do not approach the Damietta barrage fair and square, but are directed to it at great velocity through a narrow and deep channel at right angles to the axis of the river, and in line, therefore, with the already unstable foundations of the barrage. Thousands of tons of stone have been thrown into the cross channel, but the depth is still about 54 feet below low water, or 36 feet below the foundations of the barrage. Borings to a depth of 100 feet show that the soil is light stuff which melts almost like sugar when in contact with water; so the present critical state of affairs requires no further demonstration.

The analysis of Nile water made for Mr. Fowler by Dr. Letheby is appended. (See next page.)

The late Dr. Letheby remarks with reference to the preceding analysis:

"The amounts of solid matter dissolved in the water range from 13.614 to 20.471 parts for 100,000 of water. The former proportion was found in the December sample, and the latter in the sample taken the month of May. It appears also that the quantity of dissolved matters gradually arises from December to June, after which, with the exception of the month of September, it as gradually falls.

"Looking at the individual constituents of the water, it will be remarked that the nitrogenous matters, as indicated by the amounts of actual and organic ammonia, as well as by the proportions of organic matter, are considerable; for in the former case the total quantity of ammonia (actual and organic) is from 0.014 to 0.0271 part per 100,000 of water, and in the latter the organic matter is from 0.929 to 3.129 parts per 100,000 of water. These proportions are largely in excess of the quantities ordinarily found in the rivers of Europe.

"The salts of lime and magnesia which are present in sulphates and carbonates are not excessive, and therefore the water is well suited for domestic purposes.

"The proportions of soda in the form of chloride are also small; but those of potash, in the state of corbonate and silicate, are rather large. This is especially the case in the samples of water taken in June, September and October, when the soluble constituents of the water have the highest fertilizing power.

"It is, however, in the suspended matters that we are to look for the chief fertilizing ingredients of Nile water: and these are most abundant in the samples collected in August and September. In the former case they amount to 149.157 parts per 100,000 of water, and in the latter to 54.257 parts. After this the proportions gradually fall to 4.772 parts, which was the quantity found in the water taken in the month of May of the present year,

RESULTS OF ANALYSIS OF SAMPLES OF NILE WATER TAKEN DURING TWELVE CONSECUTIVE MONTHS.

Constituents per 100,000 Parts.	1874.							1875.				
	June 8.	July 10.	Aug 12	Sept. 20.	Oct. 12.	Nov. 12.	Dec. 12.	Jan. 23.	Feb. 12.	March.	April.	May 13.
Actual or saline ammonia	0.0057	0.0129	0.0043	0.0100	0.0071	0.0064	0.0049	0.0087	0.0048	0.0036	0.0035	0.0014
Ammonia from organic matter	0.0114	0.0100	0.0071	0.0071	0.0143	0.0114	0.0108	0.0143	0.0166	0.0086	0.0107	0.0118
Dissolved matters. Lime	4.167	3.992	4.422	4.260	2.309	4.304	4.264	4.468	4.057	4.631	4.763	5.178
Magnesia	1.623	1.513	1.030	0.617	0.483	1.132	0.926	1.029	0.874	0.977	0.823	1.029
Soda	1.201	0.744	0.587	0.301	0.504	0.318	0.369	0.347	0.307	0.594	0.830	1.301
Potassa	2.475	1.062	1.501	4.120	2.348	1.329	1.002	0.831	0.934	0.728	0.609	0.404
Chlorine	1.643	0.851	0.628	0 209	0.491	0.207	0.276	0.242	0.251	0.613	0.916	1.737
Sulphuric acid	2.808	2.838	1.837	1.996	1.908	1.911	1.764	1.960	1.813	2.263	2.009	2.931
Phosphoric acid	trace	trace	trace	trace	trace	trace	trace	trace	trace	trace	trace	trace
Nitric acid	trace	trace	trace	trace	trace	trace	trace	trace	trace	trace	trace	trace
Silica, &c	0.701	0.713	1.129	1.257	1.843	0.986	0.814	0.857	0.729	1.271	0.714	0.671
Organic matter	1.500	1.057	1.186	1.929	2.414	1 343	0.929	1.286	1.586	2.086	2.586	3.129
Carbonic acid and loss	4.182	3.616	4.281	4.754	3.557	3.427	3.270	3.451	4.120	4.651	4.936	4.091
Total on evaporation	20.300	16.386	16.601	19.443	15.857	14.957	13.614	14.471	14.671	17.814	18.186	20.471
Suspended matters:												
Organic matter	0.829	9.114	18.414	5.914	4.586	3.686	1.943	1.914	1.086	0.686	0.514	0.943
Mineral matter	6.086	8.729	130.743	48.343	33.214	30.686	26.971	14.829	11.486	4.629	6.114	3.829
Total suspended	6.915	17.843	149.157	54.257	37.800	34.372	28.914	16.743	12.572	5.315	6.628	4.772

"It appears also that the proportions of phosphoric acid and potassa, which are the chief mineral ingredients of agricultural value in the suspended matters of Nile water, are more abundant in the August and September samples than in those obtained at any other time of the year. This will be evident from the following table, which shows the percentage composition of well dried Nile mud in the two periods referred to:

Percentage Composition of the Sedimentary Matters from Nile Water.

	Samples taken in Aug. and Sept.	Samples taken later in the year.
Organic matters	15.02	10.37
Phosphoric acid	1.78	0.57
Lime	2.06	3.18
Magnesia	1.12	0.99
Potassa	1.82	1.06
Soda	0.91	0.62
Alumina and Oxide of iron	20.92	23.55
Silica	55.09	58.22
Carbonic acid and loss	1.28	1.44
Total	100.00	100.00

"The conclusions from these results are:

"1st. That the fertility of the Nile water is due to the organic matter, and to the salts of potash and phosphoric acid dissolved and suspended in it.

"2d. That these constituents are most abundant in the water during the months of August, September and October, when the river is in flood; and that it is during the period of inundation that the sedimentary matter, or mud, deposited from the water, is most valuable as a fertalizing agent."

Professor Wanklyn read a paper* on his analysis of the monthly samples of Nile water furnished him by the Author, and drew attention to the remarkable alteration in the proportion of chlorine, and the constancy of the hardness. His explanation of this is that storm water sweeps over the surface of a country without penetrating far into the ground, and as the surface has long been denuded of salt, very little chlorine is found in the Nile at flood. When the river has fallen, the water which has soaked into the soil drains back into the Nile, not only concentrated by evaporation, but charged with chlorine extracted from extensive strata; so it is no matter for surprise that the water at low Nile contains six to eight times as much chlorine as the flood water. The hardness is due chiefly to finely divided carbonate of lime, and the slight variation in hardness is due, according to Professor Wanklyn, to the varying amount of carbonic acid present in the river.

Well water is necessarily more heavily charged with salts than the Nile at the worst. This is clearly evidenced by the following abstract of the analysis of the water in some wells near Cairo, and in the river:

	Well Water.	Nile Water.
Chlorine (per 100 parts)	7.28 to 25.4	0.21 to 1.74
Soda	5.13 " 10.75	0.30 " 1.30
Magnesia	2.81 " 7.91	0.48 " 1.62

Farther south, in the region of tropical rains, well water is still more impure. In 1876 Mr. Fowler, acting on the Khedive's instructions, sent an expedition, consisting of twelve engineers, one hundred and fifty soldiers, and four hundred camels, to explore the country between Aboo-Goosi on the Nile, and El Fascher in Darfour, and samples of water were brought from all the more important wells. In one of these, about 15 feet deep, situated at Mahtoul, 37 miles from the Nile, the quantity of common salt contained in the water was no less than 73 grains per gallon, and in few others was it less than 50 grains.

Observations of the fluctuations in the level of the water in Egyptian wells afford interesting data with respect to the rate of filtration through fine sand. In 1867–68 daily records were kept of the varying level of the water in the Nile at Assouan and at Cairo, and in a well situated $1\frac{1}{4}$ miles from the river at the latter place. The following table shows the height of water in the Nile, and in the well at Cairo, in meters above the low Nile of 1867, at intervals of ten days:

* See 'Water Analysis,' 5th edition. London, 1879.

	10th.		20th.		28th to 31st.	
	Nile	Well	Nile	Well	Nile	Well
January ...	2.03	2.35	1.86	2.20	1.70	2.05
February ..	1.55	1.92	1.45	1.76	1.35	1.65
March.....	1.18	1.47	0.81	1.36	0.69	1.30
April.....	0.62	1.18	0.56	1.05	0.45	0.87
May.....	0.40	0.68	0.28	0.57	0.14	0.42
June.....	0.05	0.27	0.00	0.08	0.50	0.05
July.....	0.75	0.00	1.13	0.10	2.06	0.28
August....	3.63	0.35	4.60	0.69	5.55	1.25
September.	5.97	1.98	5.73	2.32	5.72	2.69
October....	5.37	2.91	5.27	3.21	6.09	3.47
November.	4.68	3.66	3.75	3.45	3.09	3.21
December .	2.54	3.02	2.40	2.80	2.18	2.56

Between July 11th and November 8th the water in the well was rising, and for the remainder of the year it was falling. In a certain sense, therefore, it may be said that the water flowed into the well from the river for four months, and into the river from the well for eight months.

At Assouan, 573 miles above Cairo, the rise commenced on June 6th, or about a fortnight earlier than at Cairo; and the maximum flood was 8.03 meters, compared with 6.09 meters at Cairo.

GREAT activity prevails at the Meudon Aëronautical School, where, says *Nature*, the French Government has established extensive works for the construction of a large number of war balloons. Each of these, 10 meters in diameter, will be made of silk, varnished by a process invented in 1794. The valve is to be made of metal, and the shape will be quite spherical. Not less than forty of them will be sent to the several French armies for the purpose of making captive or free ascents when required. Of these more than half have been already constructed. The construction of furnaces for the preparation of pure hydrogen has not begun yet. The warehouse is large enough to contain inflated balloons, which can find exit by the roof. All the men and officers —except one—belong to the corps of military engineers. The works for building directing balloons have been stopped.

A French scientist recommends the use of glycerine to prevent the formation of scale in boilers, in the proportion of 1 lb. of glycerine to every 300 or 400 lbs. of coal burned.

WHAT IS MORTAR ?

From "The Building News."

THERE could not be a more puzzling question put to one whose experience was limited to the building practices of the metropolis, for, within its wide extent, there are many varieties of mortar used for the purposes of construction. The word itself is of ambiguous origin, but its derivation is generally supposed to have been derived, like many other good building names and practices, from the Romans, who required that the lime used by them should be rendered thoroughly homogeneous, and its particles perfectly reduced in the "mortarium" before being used. In addition to this precaution, it was also the custom, more especially during the reign of the Emperor Augustus, that a preliminary probation of two years should take place before even the mortar was permitted to be used for building purposes. The general application of the word "mortar" may be regarded as being applied generically, for there is no absolute value attached to the term in itself, and by itself. Mortar being a compound concocted of such variable ingredients, and subject to a great variety of treatment, no specific value or estimation is possible, unless it is described as being composed of a certain quality of lime, to be mixed with a definite quantity of sand.

The best and most desirable property in a good mortar is, that the materials of which it is composed shall not only be competent to secure profitable coherency of its component parts, but also possess the quality of adhesiveness, and thus bind together the bricks or other forms in the building in which it may be used.

The Romans, dealing generally with lime derived from comparatively pure carbonates, resorted to many schemes for overcoming the tendency of limes obtained from such sources either to part too readily with their water of hydration, or

not to part with it at all. If from the first cause, the result would be a dusty, pulverized mass, and, if from the latter, a wet pasty product, both alike incompetent to secure their own coherency, or impart any benefit to the materials with which they were associated. Hence, we find in the best remains of the old Roman mortars a careful and perfect blending of the lime with the sand, and, generally, the insertion of thin porous tiles or bricks to absorb any superfluity of moisture, while, for hydraulic purposes, puzzolano and trass were used in combination with pure limes for works under, or in, water. For whatever purposes, and under all circumstances, it was a condition imposed upon all engaged in building operations that the ingredients of which the mortar was composed should be intimately mixed together.

From a full appreciation of the benefits to be derived from a careful blending of the lime and sand, the early English engineers and architects resorted to the practice of beating the mortar. Smeaton adopted that mode of preparing his Eddystone mortar for the famous lighthouse, and it is from that starting point we first begin to understand the value of the impure limestone, which had, until that time, almost been regarded as worthless for building purposes. Chemical knowledge, such as it was at that period, assisted in estimating the true value of those impurities, and Smeaton's labors, guided by such rules as he could command, clearly indicated the source from which the Lias limes more especially derived their hydraulicity or water-setting capacity. The advantage of so valuable a property enabled the engineer to construct docks, harbors, and such works fearlessly: but this discovery had even a much wider influence, for it proved that limes derived from such sources possessed the hitherto unknown faculty of cohesiveness. The importance of this valuable property secured the advantage of not only holding bricks, and such like materials, together by the force of adhesion, but it also commanded that which had not, until then, been accomplished—unless by the introduction of foreign substances—namely, the perfect cohesion of the mortar itself. Common mortars, derived from pure carbonates of lime, possessed, in a high degree, the capacity of adhesiveness; but they were unable to maintain their own coherency unless their particles were accurately separated by the introduction of sand, or other suitable mechanical agency. Hitherto, the engineer and architect were troubled by the necessity of perfectly slaking the lime before it could be profitably combined with the sand, and many ingenious practices were resorted to, by the aid of water and air, to accomplish this desirable object. The new limes, however, containing silica, alumina, &c., were difficult to slake, and the practice of grinding the lime was introduced, which not only permitted its accurate combination with the sand, but secured another advantage, inasmuch as lime so treated could be kept for a length of time when carefully packed and protected from the air. This great advantage was originally realized by Smeaton, who was enabled to use some of the lime prepared for the Eddystone Lighthouse, several years after the completion of that great building, in other engineering works in the North of England.

It would have been well for the country especially, and for the reputation of constructors, especially if the lines on which Smeaton and his contemporaries worked had received more attention and consideration at the hands of their successors. The beginning of this century, however, owing to the great increase in the prosperity of the country, necessitated the erection of extensive works in canals and docks, involving the employment of a new element in construction, in the shape of the contractor. This new system relieved the engineer of much of his proper duties, and, at the same time, practically deprived him of the onus of carrying on the works, and certainly took out of his hands the personal accurate conduct and control of the details of their execution, for the success and efficiency of which he was primarily responsible. The decadence of materials and quality of work may be said to date from this time, not altogether from the apathy of the engineering control, but because works were undertaken beyond the means which could be commanded for their completion. The contractor, therefore, became master of the situation, and continued, in many cases, the progress of the works

at his own risk, and with his own means; and, under such circumstances, the quality of the work could not be very efficiently controlled, or even challenged, by the engineer. To show what evil results sprang from such contractors' work, we will mention a striking instance in connection with one of the earliest metropolitan lines, which was finished, and, indeed, almost entirely made, by a well-known contractor. After holding the line of railway in pawn for some years, until he was paid for the work he had done, he at last transferred it to the company, who not only prospered, but, in course of time, the line, which was entirely on brick arches, required widening, the execution of which was let to another well-known and more modern extensive contractor. In the course of the progress of the work, the engineer in charge complained of the bad quality of the brickwork; but the contractor, pointing to the old work, said, "Mine is better than that"; to which he received for answer—"The contractor who did that work *paid himself*, but I have the money ready to pay you, and I must insist, therefore, on its quality being unexceptional." This ancedote is given to show that the necessity for continuing work, in the absence of legitimate funds to pay for it, led to a practical abandonment of the proper engineering control. This was the period, however, when work was being done in an improper manner, and may be regarded as the beginning of the demoralization of the workman, who became the tool of the rapacious middleman, who, in his rapid race for wealth, became heedless of the quality of his work, so long as it was profitable. The legacy of this recklessness was to modern builders a most damaging one; for it resulted, as we hope to show in this discussion of the mortar question, in the present lamentable disregard of the quality of building materials in general, and the lime and sand in particular. It was at or about this period that the advent of the mortar-mill took place, which practically added to the opportunities of disguising the quality of the mortar, while it professed to add to its value. The sub-letting of brickwork—the materials being supplied by the contractor—by the rod or yard, completed the debasement of the work so carelessly controlled; the selected workman, who in his turn became a sub-contractor, disregarded thickness of joints, quality of brick or mortar, so long as he could speedily *throw* it together, and raising the biggest heap in the shortest time, was his first and indeed only study.

The primary duty required of mortar, whatever may be its quality, is to connect together bricks or stones, and the amount of it used for that purpose need not be very great. Indeed, when large blocks of stone are used, and when the required amount of accuracy is bestowed on the dress of their beds, the mortar may be simply regarded as a cushion in which is dissipated the pressure caused by the weight of the block. In ancient masonry, such as that which was employed in the building of the city of Jerusalem, the joints were so thin that with difficulty a knife could be thrust into them, and in many other ruins of antiquity the stability of the building was dependent on the faultless character of the stone dressing, without reference to the bedding joint of mortar. We had in London a few years ago, a good illustration of the effects of pressure from large blocks in the case of the bridge over Farringdon street, carrying the Holborn Viaduct. The beautiful granite columns or piers, from the Island of Mull, showed indications of fracture, and it was found, after considerable discussion and altercation among experts, that the damaging influence was due to the absence of a cushion, or interposing elastic substance between the joints, which would have dispersed and nullified the vertical thrust of the hard crystalline surfaces against each other. Sheet-lead was used, and the remedy, an easy and simple one, overcame the difficulty, and succeeded in maintaining the integrity of a structure of which the city authorities and their engineers may well be proud.

Thickness of joints, especially in brickwork, has always been a matter of discussion, and ofttimes of dispute, between architect and builder, and while the one contended for a thin joint as more becoming to the elevation of his design, the other, regardless of appearance, and limiting his vision to the profit point, made the mortar-joints as thick as the

supervising authority (sometimes, we fear, not over vigilant) would allow. Specifications prescribing that so many courses of brickwork should measure so many inches had not much deterrent influence in controlling the character of the work, and now mortar-joints may be said to be of divers thicknesses, as well as qualities. Mortar of the usual kind is not expensive, and the thick joints, while facilitating the laying of the bricks, provides a system of handling by the workmen not at all calculated to improve the appearance of the work, or add to its stability. A brick is easily laid in a soft *mess*, for the bricklayer almost throws it down, and finishes its imbedment by an artful blow from the handle of his trowel, which is followed by an equally effective stroke of the trowel-blade along the joints, completing, in a shorter time than we have taken to describe it, the laying of a brick.

Thick joints, of whatever kind of lime-mortar they may be made, are simply, from our point of view, wasteful, and, what is much worse, useless. The duty of a mortar joint, as we have already said, is to adhere the surfaces of the brick together, just as two pieces of wood are joined by the aid of glue, or other similar binding agent. In the case of wood joining, no superfluity of glue is permissible, because the joint would be weakened if more was used than was absolutely necessary for the purpose required. The same rule is especially applicable to mortar joints, and, if possible, with more necessity for accuracy. Excess of lime, or its careless admixture with sand, renders such a mortar quite incompetent to perform the duty for which it is primarily destined. Lime obtained from chalk and other pure carbonates has no cohesive capacity, and its only useful faculty in construction is its quality of adhesiveness, and, therefore, such limes by themselves cannot, under the most favorable conditions, ever become indurated. They will either become pasty or powdery masses, according to the conditions of their surroundings. Alberti relates that he saw lime in a trench which was, from good presumptive evidence, five hundred years old, and it was then still moist as "honey or marrow." The proof of the dustiness of modern mortar is unhappily too widespread in our day to permit us to doubt of its existence; for whenever an old building is being pulled down, the dust shows that *mortar* existed only in name: even the mortar taken down with Temple Bar was merely pulverulent in character.

Various theories as to the recarbonization and silicisation of mortar prevailed in past times, leading the confiding builder to hope that, however defective his manipulation and materials were, Nature would assist in ultimately indurating the mortar. This somewhat fallacious view has received a shock at the hands of the modern chemist, who clearly demonstrates that even the mortar used in the Great Pyramids of Cheops has not even yet become perfectly recarbonated, while the mortar of Burgh Castle, Suffolk (a Roman garrison), has been shown not to have received any adventitious aid from its well-proportioned siliceous aggregates. There cannot be, or at least should not be, any comfort sought for by the builder, therefore, in that direction, and he must, if he desires to produce a good mortar, prepare it on the only legitimate lines based on a thorough scientific as well as common-sense examination of the question.

Mortar, of whatever kind, receives good or bad influences through the quality of the bricks or stones with which it is brought in contact, and, therefore, some degree of attention is required to secure the best constructive results. Differences in the porosity of bricks, for instance, have much to do with the beneficial action of the mortar, as has been shown by some experiments with Staffordshire moderately-glazed blue bricks, hard grey stocks, and soft place-bricks The two Staffordshire bricks, jointed with blue lias lime mortar, at the end of one month were separated by a force of 40lbs. per square inch, grey stocks by a pull of 36lbs. per square inch, while the soft place-bricks were pulled asunder with a force of 18lbs. per square inch. In this case the lowest result was reached through the softest material, which, doubtless owing to its excessive porosity, robbed the mortar, while setting, of its water of hydration too speedily. In another series of experiments, the lowest value was found to be from the hardest stone, the results being as

follows: Granite being equal to 11 and Portland stone 16 in relative adhesive value, the cementing agent in that case being Portland cement, so that while providing against the dangers of improper mortar, one of those not to be disregarded is the capacity of absorption in the bricks. Drenching the bricks does not, in fact, secure immunity at all times from this danger, for during exceptionally warm weather, the evaporation of the water would speedily follow, and the spongy brick would in such a case rob the mortar of its moisture.

What are the precautions required to protect buildings against the dangers common to the preparation of mortars and their use? We need not with any degree of particularity enumerate in an essay of this kind, necessarily so general in its character, the exact details, but we may briefly state that, above all things, it is essential that, of whatever proportions the mortar may be composed, accuracy of the mixture may be obtained. Proportion must always be an important factor in this question, because the quality and character of both lime and sand influence the calculations, which must, under intelligent conditions, determine on how much of one and the other should be used. Properly decarbonized lime, and all the details of its manufacture strictly perfect in character, ought to secure a matrix competent to blend with, or become incorporated with, any kind of suitable aggregate. Under any circumstances, the sand should be naturally clean, or, if foul and loamy in character, freed by washing from any impurities which could interfere with its profitable mixture with the lime. Fine sand would require a larger proportion of lime than one coarse in character, because it is a necessary condition of success in mortar-making that every particle of aggregate should be perfectly covered with lime; otherwise, the cementitious result would be defective. Fine granules increase the surfaces, and, therefore, to coat them with advantage, a more diffusive state of the lime is indispensable; otherwise, there would be vacuities, calculated to impair the coherency of the mortar, for the particles of sand, under ordinary conditions, could not be brought into sufficiently accurate contact with each other. Coarse sand is more suitable for mortar-making purposes when there is sufficient fine stuff to fill up the voids, resulting from the impossibility of forming a compact mass with such materials, and less time would be required, because there would be, in such a case, more limited surfaces to require coating from the cementing agent. The whole process, under whatever circumstances, should be mainly directed to secure well-balanced proportions, without a superfluity of either matrix or aggregate. Sands vary in texture according to the source from which they are obtained; but, generally speaking, they are composed of spherical particles, more or less hard in texture, according to the geological source from which they were originally derived. Pit-sands are not usually so favorable as those obtained from the river, or other similar sources, because they are usually associated with fine silt or loam, either contemporaneous with their original deposit or subsequently infiltrated by water action from surface sources.

Modern mortar-joints, according to our argument, are simply wasteful in their character, and, practically, exert no beneficial influence on the brickwork with which they form so conspicuous an adjunct. There is a double duty which should be forthcoming from the mortar-joints, although we fear it is never looked upon except in its single sense, that of keeping the bricks together. The other duty, that of protecting the arrises of the bricks from degradation, is a no less important one than the other, for if the mortar-joint dusts out, or is washed out by the action of the weather, the sharp angles of the bricks become rounded, and the first act of decay sets in. The Romans, famous for their attention to, and sensible knowledge of, mortar, erected buildings in many countries which still endure, when the buildings of the Middle Ages have crumbled away. Those who take the trouble to examine some of the old feudal strongholds of our own land cannot fail to see that their decay is due to the weather action of the mortar-joints, except where the concrete form of wall was adopted, and, under such circumstances, a much more durable example is apparent.

Some of our architects and engineers, without giving the question of mortar the necessary intelligent consideration,

commit the equally reprehensible practice of using too much lime in their mortar. The results of this are apparent in the unsightly discoloration of the fronts of buildings in the architectural direction, and in that of the engineering division of construction, in the numerous stalactites under the soffits of the arches of railway and other bridges. The exudence of lime in these cases is due to its having been used in excess in the mortar, and the action of water washes it out of the so-called mortar mass. There could have been no substantial coherence of the mortar under such circumstances, for the presence of *unmixed* lime was calculated to degrade, and, in the end, probably leave the sand in a state of impoverishment, at least so far as the cementing agent was concerned.

The mortar question is essentially within the control of the constructor, and we hope that these remarks will lead up to a better appreciation of a subject which has, during recent times, had but scant attention. The modern tendency to improve brickwork will doubtless result in an eventual improvement in mortar joints, for accurately laid bricks, of the bright red color of to-day, must have clearly defined joints of minimum thickness, and the pleasing surfaces must not be disfigured by the exuding lime from badly proportioned mortars.

In large works the mortar-mill takes a more prominent place than its merits deserve, and we fear that much of the bad mortar of to-day is due to the carelessness which the use of such a machine involves. While claiming the advantages of mixing lime and sand, the mortar-mill induces many malpractices, and favors the introduction into the mortar of substances ill calculated to improve its quality. Public mortar-mills are common in some towns in the North of England, where mortar can be purchased ready for use at so much a ton. Such accommodation would be most useful to the builders, were the materials of which the mortar was composed and thus manipulated true in kind and character. We fear, however, judging from the placards usually posted up in a prominent place near these mortar manufactories, that the best materials are not used, for they invite the delivery of all kinds of dry rubbish for mixing in their mortar-mill. We were sorry to find, the other day, a similar invitation at a large building in a London suburb.

To mix lime and sand thoroughly, and to secure that their quality was proper, could be beneficially done by a different kind of a machine, and the mortar, in its dry state, thus mixed, sold in sacks, ready for subsequent hydration by a careful addition of the required moisture. Mortar thus provided would be capable of easy challenge, and we think it would be less costly than the now existing clumsy and irrational preparation, surrounded as it undoubtedly is, by numerous dangers. Better reduce the extent of the joints, and use less mortar, more especially when it is evident that the present superfluity is not only wasteful, but dangerous. In the recent disaster at Finsbury Park, the thick mortar joints exerted no protective influence when the settlement of the foundations of the wall occurred; but had the mortar been composed of first-class Portland cement and good sharp sand, the wreck of a sightly building would have been more circumscribed in its extent.

When the controlling authorities, whose duty it ought to be to examine and test the quality of building materials, awaken to a sense of their position, we will no longer dread the possibility of living in houses surrounded with dangers owing to their constructive defects; for bad bricks and bad mortar would then be, as they ought now to be, regarded as simple destructives of health and comfort.

Compound Locomotives.—M. Mallet's system of compounding locomotives is, we are glad to hear, shortly to have a trial in Germany, two engines on this system having been ordered from the Schichau Works at Elbing for the Hanoverian State Railways. These locomotives are intended for local service, and have high and low pressure cylinders respectively 8.87 in. and 11.81 in. diameter, the stroke in each case being 15.75 in., and the relative volumes being thus 1:2.25. The engines have coupled wheels 44.5 in. in diameter, and the weight in working order will be 15 tons. The boilers have 5.8 sq. ft. of grate surface, and 226 sq. ft. of heating surface, and are to be worked at a pressure of 177 lbs. per square inch.

COMPARATIVE STRUCTURE OF ARTIFICIAL SLAGS AND ERUPTIVE ROCKS.

By H. C. SORBY, LL.D., F.R.S., &c.

An Address before the Geological Section of the British Association at Swansea.

In selecting a subject for an address to be given in accordance with the custom of my predecessors, I was anxious that it should be in some way or other connected with the locality in which we have met. If I had been adequately acquainted with the district, I should have thought it incumbent on me to give such an outline of the general geology of the surrounding country as would have been useful to those attending this meeting. I am, however, practically a stranger to South Wales, and must therefore leave that task to others. On reflecting on the various subjects to which I might have called your attention, it appears to me that I could select one which would be eminently appropriate in a town and district where iron and copper are smelted on so large a scale, and, as I think, also equally appropriate from a geological point of view. This subject is the comparative structure of artificial slags and erupted rocks. In making this choice I was also influenced by the fact that in my two anniversary addresses, as President of the Geological Society, I have recently treated on the structure and origin of modern and ancient stratified rocks, and I felt that, if in the present address I were to treat on certain peculiarities in the structure of igneous rocks, I should have described the leading conclusions to which I have been led by studying the microscopical structure of nearly all classes of rocks. It would, however, be impossible in the time now at disposal to treat on all the various branches of the subject. Much might be said on both the purely chemical and purely mineralogical aspects of the question; but though these must not be ignored, I propose to draw your attention mainly to another special and remarkable class of facts, which, so far as I am aware, have attracted little or no attention, and yet, as I think, would be very instructive if we could fully understand their meaning. Here, however, as in so many cases, the observed facts are clear enough, but their full significance is somewhat obscure, owing to the want of adequate experimental data, or of sufficient knowledge of general physical laws.

A considerable amount of attention has already been paid to the mineral constitution of slags, and to such peculiarities of structure as can be learned independently of thin microscopical sections. A very complete and instructive work, specially devoted to the subject, was published by von Leonhard about twenty-two years ago, just at the time when the microscope was first efficiently applied to the study of rocks. Since then, Vogelsang and others have described the microscopical structure of some slags, in connection with their study of obsidian and other allied volcanic rocks. At the date of the publication of von Leonhard's work the questions in discussion differed materially from those which should now claim attention. There was still more or less dispute respecting the nature and origin of certain rocks which have now been proved to be truly volcanic by most unequivocal evidence. I am not at all surprised at this, since, as I shall show, there is such a very great difference in their characteristic structure and that of the artificial products of igneous fusion, that but for the small portions of glass inclosed in the constituent crystals, described by me many years ago under the name of "glass-cavities," there would often be no positive proof of their igneous origin. There was also considerable doubt as to the manner in which certain minerals in volcanic rocks had been generated. The observed facts were sufficient to prove conclusively that some had been formed by sublimation, others by igneous fusion, and others deposited from more or less highly-heated water, but it was difficult or impossible to decide whether in particu-

lar cases certain minerals had been formed exclusively by one or other process, or sometimes by one and sometimes by the other, or by the combined action of water and a very high temperature. I must confess that, even now that so much may be learned by studying with high magnifying powers the internal structure of crystals, I should hesitate very much in deciding what were the exact conditions under which certain minerals have been formed. This hesitation is probably as much due to inadequate examination, and to the want of a complete study of typical specimens, both in the field and by means of the microscope, as to the unavoidable difficulties of the subject. Such doubt, however, applies more to the origin of minerals occurring in cavities than to those constituting a part of true rock masses, to which latter I shall almost exclusively refer on the present occasion. In the formation of these it appears to me that sublimation has occurred to a very limited extent. In many cases true igneous fusion has played such a leading part that the rocks may be fairly called *igneous*, but, in other cases water in some form or other has, I think, had so much influence, that we should hesitate to call them *igneous*, and the term *erupted* would be open to far less objection, since it would adequately express the manner of their occurrence, and not commit us to anything open to serious doubt.

In studying erupted rocks of different characters we see that at one extreme they are as truly igneous as any furnace product, and at the other extremity hardly, if at all, distinguishable from certain deposits met with in mineral veins, which furnish abundant evidence of the preponderating, if not exclusive, influence of water, and have very little or nothing in common with products certainly known to have been formed by the action of heat, and of heat alone. Between these extremes there is every connecting link, and in certain cases it is almost, if not quite, impossible to say whether the characteristic structure is due more to the action of heat than of water. The great question is whether the presence of a small quantity of water in the liquid or gaseous state is the true cause of very well-marked differences in structure, or whether greater pressure and the necessarily slower rate of cooling were not the more active causes, and the presence of water in one state or another was merely the result of the same cause. This is a question which ought to be solved by experiment, but I fear it would be almost impossible to perform the necessary operations in a satisfactory manner.

What I now propose to do is to describe a particular class of facts which have lately attracted my attention, and to show that the crystalline minerals in products known to have been formed by the action of heat alone have a certain very well-marked and characteristic structure, which is gradually modified as we pass through modern and more ancient volcanic to plutonic rocks, in such a manner as to show at once that they are intimately related, and yet differ, in such characteristic particulars that I think other agencies than mere heat must have had great influence in producing the final results.

In dealing with this subject I propose in the first place to describe the characteristic structure of products formed artificially under perfectly well-known conditions, and then to pass gradually to that of rocks whose origin must be inferred, and cannot be said to have been completely proved.

Crystalline Blowpipe Beads.—Some years ago I devoted a considerable amount of time to the preparation and study of crystalline blowpipe beads, my aim being to discover simple and satisfactory means for identifying small quantities of different earths and metallic oxides, when mixed with others, and I never supposed that such small objects would throw any light on the structure and origin of vast masses of natural rock. The manner in which I prepared them was as follows: A small bead of borax was so saturated with the substance under examination at a high temperature that it became opaque, either on cooling or when slowly reheated. It was again fused so as to be quite transparent, and then very slowly cooled over the flame. If properly managed, the excess of material held in solution at a high temperature slowly crystallized out, the form and character of the crystals depending on

the nature of the substance and on the presence of other substances added to the bead as test reagents. By this means I proved that in a few exceptional cases small simple solid crystals are formed. More frequently they are compound, or occur as minute needles, but the most characteristic peculiarity is the development of complex skeleton crystals of extreme beauty, built up of minute attached prisms, so as to give rise to what would be a well-developed crystal with definite external planes, if the interspaces were all filled up.

In many cases the fibers of these skeletons are parallel to three different axes perpendicular to one another, and it might be supposed that the entire skeleton was due to the growth of small needle-shaped crystals, all uniformly elongated in the line of one crystalline axis, so that the resulting mass would be optically and crystallographically complex; but in some cases the different systems of fibers or needles are inclined obliquely, and then the optical characters enable us to prove that the separate prisms are not similar to one another, but developed along different crystalline planes, so as to build up one definite crystal, mechanically complex, but optically and crystallographically simple, or merely twinned. In a few special cases there is a well-pronounced departure from this rule, and truly compound groups of prisms are formed. In the center there is a definite simple prism, but instead of this growing continuously in the same manner, so as to produce a larger prism, its ends, as it were, break up into several smaller prisms slightly inclined to the axis of the first, and these secondary prisms in like manner break up into still smaller, so as ultimately to give rise to a curious complex, brush-like growth, showing in all positions a sort of fan-shaped structure, mechanically, optically, and crystallographically complex.

I have done my best to describe these various kinds of crystals seen in blowpipe beads as clearly as can be done without occupying too much time, but feel that it is impossible to make the subject as simple as it really is without numerous illustrations. However, for the purpose now in view, it will I trust suffice to have established the fact that we may divide the crystals in blowpipe beads into the following groups, which, on the whole, are sufficiently distinct, though they necessarily pass one into the other:

1. Simple crystals.
2. Minute detached needles.
3. Fan-shaped compound groups.
4. Feathery skeleton crystals.

It must not be supposed that crystals of one or other of these groups occur promiscuously and without some definite relation to the special conditions of the case. Very much depends upon their chemical composition. Some substances yield almost exclusively those of one group, and other substances those of another, whilst in some cases a difference in the rate of cooling and other circumstances give rise to variations within certain limits; and, if it were possible to still further vary some of the conditions, these limits would probably be increased. Thus, for example, the earliest deposition of crystalline matter from the glossy solvent is sometimes in the form of simple solid prisms or needles, but later on in the process it is in the form of compound feathery tufts; and, if it were possible to cool the beads much more slowly whilst they are very hot, I am inclined to believe that some substances might be found that in the early stage of the process would yield larger and more solid crystals than those commonly met with. This supposition at all events agrees with what takes place when such salts as potassium chloride are crystallized from solution in water. Some of my blowpipe beads prove most conclusively that several perfectly distinct crystalline substances may be contemporaneously deposited from a highly-heated vitreous solvent, which is an important fact in connection with the structure of igneous rocks, since some authors have asserted that more than one mineral species cannot be formed by the slow cooling of a truly melted rock. The great advantage of studying artificial blowpipe beads is that we can so easily obtain a variety of results under conditions which are perfectly well known, and more or less completely under control.

Artificial Slags.—I now proceed to consider the structure of slags, and feel tempted to enter into the consideration

of the various minerals found in them, which are more or less perfectly identical with those characteristic of erupted rocks, but some of the most interesting, like the felspars, occur in a well-marked form only in special cases, where iron ores are smelted with fluxes, seldom if ever employed in our own country, so that my acquaintance with them is extremely small. My attention has been mainly directed to the more common products of our blast furnaces. On examining these, after having become perfectly familiar with the structure of blowpipe beads, I could see at once that they are very analogous, if not identical, in their structure. In both we have a glassy solvent, from which crystals have been deposited; only in one case this solvent was red hot melted borax, and in the other glassy, melted stone. Thus, for example, some compounds, like what I believe is Humboldtilite, crystallize out in well-marked solid crystals, like those seen occasionally in blowpipe beads, whereas others crystallize out in complex feathery skeletons, just like those so common in, and characteristic of, the beads. In both we also often see small detached needles scattered about in the glassy base. These skeleton crystals and minute needles have been described by various writers under the names *crystallites*, *belonites*, and *trichites*. Though we have not the great variety of different forms met with in the beads, and cannot so readily vary the conditions under which they are produced, yet we can at all events see clearly that their structural character depends both on their chemical constitution and on the physical conditions under which they have crystallized. None of my microscopical preparations of English slags appear to contain any species of felspar, but several contain what I believe is some variety of augite, both in the form of more or less solid prisms, and of feathery skeletons of great beauty and of much interest in connection with the next class of products to which I shall call your attention, viz: rocks artificially melted and slowly cooled.

Rocks Artificially Melted.—I have had the opportunity of preparing excellent thin microscopical sections of some of the results of the classic experiments of Sir James Hall. I have also carefully studied the product obtained by fusing and slowly cooling much larger masses of the basalt of Rowley, and have compared its structure with that of the original rocks. Both are entirely crystalline, and, as far as I can ascertain, both are mainly composed of the same minerals. Those to which I would especially call attention are a triclinic felspar and the augite. The general character of the crystals is, however, strikingly different. In the artificial product a considerable part of the augite occurs as flat, feathery plates, like those in furnace slags, which are quite absent from the natural rock, and only part occurs as simple solid crystals, analogous to those in the rock, but much smaller and less developed. The felspar is chiefly in the form of elongated, flat, twinned prisms, which, like the prisms in some blowpipe beads, commence in a more simple form and end in complex fan-shaped brushes, whereas in the natural rock they are all larger than in the artificial, and exclusively of simple characters. On the whole then, though the artificially melted and slowly cooled basalt is entirely crystalline, and has a mineral composition closely like that of the natural rock, its mechanical structure is very different, being identical with that of blowpipe beads and slags.

Volcanic Rocks.—Passing now to true natural igneous rocks, we find some like obsidian, which closely correspond with blowpipe beads, slags, and artificially melted rocks, in having a glassy base through which small crystalline needles are scattered; but the more completely crystalline volcanic rocks have, on the whole, a structure very characteristically unlike that of the artificial products. I have most carefully examined all my sections of modern and ancient volcanic rocks, but cannot find any in which the augite or magnetite is crystallized in feathery skeletons. In the case of only one single natural rock from a dyke near Beaumaris have I found the triclinic felspar arranged in just the same fan-shaped, brush-like groups, as those in similar rocks artificially melted and slowly cooled. The large solid crystals in specimens from other localities sometimes show that towards the end of their growth small flat prisms have

developed on their surface, analogous to those first deposited in the case of the artificial products. In slags composed almost exclusively of what I believe is Humboldtilite, the crystals are indeed uniformly as simple and solid as those in natural rocks, but the examination of different blowpipe beads shows that no fair comparison can be made between altogether different substances. We must compare together the minerals common to the natural and the artificial products, and we then see that, on the whole, the two classes are only just distinctly connected by certain exceptional crystals and by structural characters which, as it were, overlap enough to show that there is a passage from one type to the other. In the artificial products are a few small solid crystals of both augite and a triclinic felspar, which closely correspond to the exceptionally small crystals in the natural rocks, but the development of the great mass of the crystals is in a different direction in the two cases. In the artificial products it is in the direction of complex skeletons, which are not seen in the natural rock, but in the natural rock it is in the direction of large simple solid crystals, which are not met with in the artificial products. There is a far closer analogy in the case of partially vitreous rocks, which, independent of the true glassy base common to them and the artificial products, often contain analogous crystalline needles. Even then, however, we see that in the artificial products the crystals tend to develop into complex skeletons, but in the natural rocks into simple solid crystals.

It must not be supposed that these facts in any way lead me to think that thoroughly crystalline modern and ancient volcanic rocks were never truly fused. The simple, large, and characteristic crystals of such minerals as augite, felspar, leucite, and olivine often contain so many thoroughly well-marked glass inclosures as to prove most conclusively that when the crystals were formed they were surrounded by, and deposited from, a melted glassy base, which was caught up by them whilst it was still melted. This included glass has often remained unchanged, even when the main mass became completely crystalline, or has been greatly altered by the subsequent action of water. I contend that these glass enclosures prove that many of our British erupted rocks were of as truly igneous origin as any lava flowing from a modern volcano. The difference between the structure of such natural rocks and that of artificial slags must not, in my opinion, be attributed to the absence of true igneous fusion, but to some difference in the surrounding conditions, which was sufficient to greatly modify the final result when the fused mass became crystalline on cooling. The observed facts are clear enough, and several plausible explanations might easily be suggested, but I do not feel at all convinced that any single one would be correct. That which first suggests itself is a much slower cooling of the natural rocks than is possible in the case of the artificial products, and I must confess that this explanation seems so plausible that I should not hesitate to adopt it if certain facts could be accounted for in a satisfactory manner. Nothing could be more simple than to suppose that skeleton crystals are formed when deposition takes place in a hurried manner, and they so overgrow the supply that they develop themselves along certain lines of growth before there has been time to solidly build up what has been roughly sketched in outline. I cannot but think that this must be a true, and to some extent active, cause, even if it be inadequate to explain all the facts. What makes me hesitate to adopt it by itself is the structure of some doleritic rocks when in close contact with the strata amongst which they have been erupted. In all my specimens the effects of much more rapid cooling are perfectly well marked. The base of the rock when in close contact is sometimes so extremely fine grained that it is scarcely crystallized, and it is certainly far less crystalline and finer grained than the artificial products to which I have called attention, and yet there is no passage towards those structures which are most characteristic of slags, or at least no such passage as I should have expected if these structures depended exclusively on more rapid cooling. We might well ascribe something to the effect of mass, but one of my specimens of basalt melted and slowly cooled in a small crucible is quite as crystalline as

another specimen taken from a far larger mass, though I must confess that what difference there is in this latter is in the direction of the structure characteristic of natural rocks. The presence or absence of water appears to me a very probable explanation of some differences. When there is evidence of its presence in a liquid state during the consolidation of the rock, we can scarcely hesitate to conclude that it must have had some active influence; but in the case of true volcanic rocks the presence of liquid water is scarcely probable. That much water is present in some form or other is clearly proved by the great amount of steam given off from erupted lavas. I can scarcely believe that it exists in a liquid state except at great depths, but it may possibly be present in a combined form or as a dissolved vapor under much less pressure, and the question is, whether this water may not have considerable influence on the growth of crystals formed prior to eruption, before it was given off as steam. I do not know one single fact which can be looked upon as fairly opposed to this supposition, and it is even to some extent supported by experiment. M. Daubrée informs me that the crystals of augite formed by him at a high temperature by the action of water have the solid character of those in volcanic rocks, and not the skeleton structure of those met with in slags. The conditions under which they were formed were, however, not sufficiently like those probably present during the formation of erupted lavas to justify our looking upon the explanation I have suggested as anything more than sufficiently plausible, in the absence of more complete experimental proofs.

Granitic Rocks.—I now proceed to consider rocks of another extreme type, which for distinction we may call the granitic. On the whole they have little or nothing in common with slags or with artificial products similar to slags, being composed exclusively of solid crystals, analogous in character only to slag-crystals of very different mineral nature. As an illustration I would refer to the structure of the products formed by fusing and slowly cooling upwards of a ton of the syenite of Grooby, near Leicester. Different parts of the resulting mass differ very materially, but still there is an intimate relation between them, and a gradual passage from one to the other. The most characteristic feature of those parts which are completely crystalline is the presence of beautiful feathery skeleton crystals of magnetite, and of long flat prisms of a triclinic felspar, ending in complex, fan-shaped brushes. There are no solid crystals of felspar, hornblende, and quartz, of which the natural rock is mainly composed, to the entire exclusion of any resembling those in the melted rock. As looked upon from the point of view taken in this address, the natural and artificial products have no structural character in common, so that I think we must look for other conditions than pure igneous fusion to explain the greatly modified results. We have not to look far for evidence of a well-marked difference in surrounding circumstances. The quartz in the natural rock contains vast numbers of fluid cavities, thus proving that water was present, either in the liquid state or as a vapor so highly compressed that it afterwards condensed into an almost equal bulk of liquid. In some specimens of granite there is indeed clear proof that the water was present as a liquid, supersaturated with alkaline chlorides, like that inclosed in the cavities of some minerals met with in blocks ejected from Vesuvius, which also have to some extent what may be called a granitic structure.

In the case of one very exceptional and interesting granite, there is apparently good proof that the felspar crystallized out at a temperature above the critical point of water—that is to say, at a temperature higher than that at which water can exist as a liquid under any pressure—and it caught up highly compressed steam, comparatively, if not entirely, free from soluble salts; whereas the quartz crystallized when the temperature was so far lowered as to be below the critical point, and the water had passed into a liquid, supersaturated with alkaline chlorides, which have crystallized out as small cubes in the fluid cavities, just as in the case of minerals in some of the blocks ejected from Vesuvius.

Confining our attention, then, to extreme cases, we thus see that rocks of the granitic type differ in a most char-

acteristic manner from the products of artificial igneous fusion, both in the structure of the crystals and in containing liquid water inclosed at the time of their formation. The question then arises whether these differences were due to the presence of the liquid water, or whether its presence and the characteristic structure were not both the effects of the great pressure of superincumbent rocks. I do not see how this can be decided in a perfectly satisfactory manner, but must confess that I am inclined to believe that, whilst great pressure was necessarily the reason why the water did not escape as vapor, the presence of liquid water during final consolidation must have had very considerable influence in modifying the structure of the rock, and had a great share in developing what we may call the granitic type.

It would be very instructive to follow out the gradual passage from one extreme type to another far more completely than is possible on the present occasion. The most interesting examples of rocks, intermediate between the granitic and volcanic types, that I have been able to examine in adequate detail, are the various Cornish elvans and other quartz felsites, which furnish all but a complete passage from pitchstone to granite. Some specimens prove that quartz may crystallize out from and inclose a perfectly glassy base, without a trace of liquid water, and at the same time other specimens prove equally well that, as we approach the granitic type, the quartz was not deposited from a glassy solvent, but inclosed more or less water. In the few intermediate cases there appears to be evidence of the conjoint presence of uncombined water and melted stony matter. On the whole, if we take into consideration only the external form of the larger crystals, rocks of the granitic type are very much as though the crystals met with in truly volcanic rocks had been strained out from the glassy or fine-grained base, and the intermediate spaces filled with quartz. The internal structure of the crystals is, however, very different, the cavities in one class containing glass, and in the other water. This most essential and characteristic difference proves that rocks of the true granitic type cannot have been formed simply by the more complete crystallization of the general base of the rock. If the crystals in granite were analogous to those developed in volcanic rocks, and the only essential difference were that the residue crystallized out more slowly and completely, so as to give rise to a more coarsely crystallized base, the crystals first formed ought not, as I think, to differ so essentially as that in one case they should inclose only glass, and in the other only water. Taking all into consideration, we can therefore scarcely suppose that the crystals in granitic rocks were deposited from a truly-melted dry glassy solvent, like those in volcanic rocks or in slags.

General Results.—I have, I trust, now said enough to show that the objects here described may be conveniently separated into three well-marked groups, viz: artificial slags, volcanic rocks, and granitic rocks. My own specimens all show perfectly well-marked and characteristic structures, though they are connected in some cases by intermediate varieties. Possibly such connecting links might be more pronounced in other specimens that have not come under my notice. I must, however, base my conclusions on what I have been able to study in an adequate manner, by examining my own preparations, and leave it for others to correct any error into which I may have been led from lack of more numerous specimens. In any case the facts seem abundantly sufficient to prove that there must be some active cause for such a common, if not general, difference in the structural character of these three different types. The supposition is so simple and attractive that I feel very much tempted to suggest that this difference is due to the presence or absence of water as a gas or as a liquid. In the case of slags it is *not* present in any form. Considering how large an amount of steam is given off from erupted lavas, and that, as a rule, no fluid cavities occur in the constituent minerals, it appears to me very plausible to suppose that those structures which are specially characteristic of volcanic rocks are in great measure, if not entirely, due to the presence of *associated* or *dissolved vapor.* The fluid cavities prove that water was sometimes,

if not always, present as a *liquid* during the consolidation of granitic rocks, and we can scarcely hesitate to conclude that it must have had very considerable influence on the rock during consolidation. Still, though these three extreme types appear to be thus characterized by the absence of water, or by its presence in a state of vapor or liquid, I think we are scarcely in a position to say that this difference in the conditions is more than a plausible explanation of the differences in their structure. At the same time I do not know any facts that are opposed to this conclusion, and we should perhaps not greatly err in thus correlating the structures, even though the water was not the essential and active cause of the differences.

Confining our attention to the more important crystalline constituents which are common to the different types, we may say that the chief structural characters of the crystals are as follows:

a. Skeleton crystals.
b. Fan-shaped groups.
c. Glass cavities.
d. Simple crystals.
e. Fluid cavities.

These different structural characters are found combined in different ways in the different natural and artificial products, and for simplicity I will refer to them by means of the affixed letters.

The type of the artificial products of fusion may generally be expressed by $a+b$ or $b+c$; that is to say, it is characterized by skeleton crystals and fan-shaped groups, or by fan-shaped groups and glass cavities. In like manner, the volcanic type may be expressed occasionally by $b+c$, but generally by $c+d$, and the granitic by $d+e$. These relations will be more apparent if given in the form of a table as follows:

Slag type.... $\left\{\begin{matrix} a+b \\ b+c \end{matrix}\right.$
Volcanic type.... $\left\{\begin{matrix} b+c \\ c+ \end{matrix}\right.$
Granitic type.....$d+e$

Hence it will be seen that there is a gradual passage from one type to the other by the disappearance of one character and the appearance of another, certain characters in the meanwhile remaining common, so that there is no sudden break, but an overlapping of structural characteristics. It is, I think, satisfactory to find that, when erupted rocks are examined from such a new and independent point of view, the general conclusions to which I have been led are completely in accord with those arrived at by other methods of study.

Conclusion.—And now I feel that it is time to conclude. I have necessarily been compelled to give only a general account of the subject, and perhaps for want of adequate description many facts may appear more complex than they really are. Some are, indeed, of anything but simple character, and their full explanation is, perhaps, beyond our present power. The greater part are, however, much more simple and easy to observe than to describe; and, even, if I have failed to make everything as plain as I could wish, I hope that I have succeeded in making the principal points sufficiently clear, to show that the structure of slags and analogous artificial products throws much light on the structure and origin of the various groups of erupted rocks. I feel that very much still remains to be learned, and, as I think, could be learned by the further extension of this method of inquiry. What strikes me most is the great necessity for the more complete appreciation of experimental methods of research; but to carry out the experiments necessary to clear up the essential difficulties of the subject would, I fear, be a most difficult undertaking. In the meantime, all that we can do is to compare the structure of known artificial products with that of natural rocks, and to draw the best conclusions we can from the facts, as viewed in the light of our present knowledge of chemistry and physics. My own impression is that there is still much to be learned respecting the exact conditions under which some of our commonest rocks were formed.

PUBLIC WORKS IN SPAIN.

From "The Building News."

That the public works of Spain should be insufficient, and badly regulated, seems to be a matter of course. With this people, whose deficiency in administrative ability makes their great country an unwieldy, disunited group of provinces; whose want of probity makes constitutional government a farce; and whose energy-lacking character looks upon civilization principally as so much more of luxury for those who have, or can get, money to purchase it—this state of things is only what is to be expected. Except in those localities where foreign intercourse, or a more progressive race than the average, prevails, public works tardily follow the demands of the country, rather than lead or develop its resources. There is movement—progress, I suppose it may be called—but it is a progress reluctantly yielding to the compulsion of the civilization of more energetic nations. Still it is not fair to judge Spain by simply comparison with other more highly civilized countries of Western Europe. She is not capable of the same development as are our own and some other favored lands. The extreme climates—the enervating summers and tempestuous winters—the barrenness of the flood-washed sand and rock soils, and the intractable mountainous character of a large portion of the surface in certain districts—render their being brought into a condition such as England or Belgium enjoys out of the question. It is not just, then, to estimate Spain's capability of supporting a population, or her proper proportion of roads and railways, by computation of her thousands of square miles, with such standards as these.

The roads, for example, are, from this point of view, very inadequate; yet, for the population and the purposes it has to serve, the system is tolerably good. I think the high roads are now, especially if the condition of other things be considered, very satisfactory. They are fairly well engineered; with, generally, good working gradients. The embankments, cuttings, bridges, and occasional tunnels, are kept in good order by a regular permanent staff of workmen, and the macadam surface of broken limestone or granite is also well kept. The "diligencias," which are not themselves models of utility or good management, have little to complain of as to their roads. Most of these vehicles now ply as feeders to the railways, in correspondence with the trains; with consequently a greater regard for punctuality than formerly. In some cases, too, the new lines of railway are commenced from both ends at once, and portions are opened as they are completed; with a connecting service of "diligencias," gradually shortening, and finally disappearing altogether. It is not long since the route to Granada was traversed thus; and, at present, the traffic from Oviedo to Leon, and from Leon westward to Lugo, has to use the same broken means of transport.

As new, or even growing cities, are in the interior rarities, nearly all the highway system is ancient. I did not see or hear of any altogether new high road; but improvement works are to be seen here and there. The approaches to some towns, upon the elevated sites favored by their founders, the Moors, which are subjects requiring some consideration, have been or are being improved. These ascents are sometimes so great as to involve zig-zags and detours of as much as a mile in length. Of course the improvements are such in a utilitarian, but not by any means, in the picturesque sense. At Toledo, the new road from the station, after crossing the river by the old bridge, "Alcantara" and making a circuit of the eastern end of the town, makes a zigzag (always rising) towards the Puerta del Sol. But it runs past this structure and alongside the fragment of the old road, instead of through it. And, artistically speaking, the grand old gate seems insulted by the disregard for its purpose. At Segovia similar works upon the principal approach were executed some time back. And at Zamora, Toro, and other elevated towns, a

reform in the entrance roads has been attendant upon the increased traffic, brought by the railway. At Avila the road from the direction of Segovia which passes under the walls of the town to the bridge, is now being reconstructed at different levels and gradients; and although there are no cuttings of any great depth, yet the granite rock which crops up through the thin soil necessitates a great deal of labor in wedging, blasting, &c.

I may note here the awakening to the usefulness of trees, which is evident in some places. Spain is sadly deficient, generally speaking, in this respect; partly, perhaps, because some sort of irrigation is almost always necessary. But one can see now in many situations near the large towns, lately-planted trees, which promise to greatly improve the parched dusty roads—notably, for numbers, near Burgos, where upon the waste lands, bordering on the river (which like most Spanish streams, shows a greed for space out of all proportion to its volume), there are some splendid "alamedes," or groves, which have been quite lately extended. These trees are principally varieties of the poplar species. But, in many localities, the elm flourishes well if supplied with water.

Some other important works, now in progress, are the improvement of the internal thoroughfares of all cities. In those few which are progressive, there are one or more new broad streets, either interesting the denser neighborhoods or extending the town toward a suburb. Some of these streets I mentioned in connection with House-building. But I reserved the notice that I wish to make of the extension of Barcelona, as belonging rather to the series of public works than to simple house-building.

Barcelona, the capital of Catalonia (called by Ford the Lancashire of Spain), overlooks the Mediterranean toward the east. It is extending with London-like rapidity over its valley, toward the hills, on the south and west sides. In the south, under the hill and fortress, which command the town, is arising a new bourgeoise quarter with wide rectangularly-planned streets and lofty houses. To the southwest, along the path of the Spanish railway, is a busy suburb of trade and manufactures. Westward, at a distance of a mile or more from the former boundary of the town lies the suburban town of Gracia, at the base, and on the lower slopes of breezy hills, upon which villas are arising in all directions. Gracia is now connected with Barcelona by a fine avenue "El Paseo de Gracia," and as this is a good representative of the modern Spanish favorite type of principal thoroughfare, I will describe it in detail.

It has first a broad central footwalk—the scene of the all-popular evening promenade—fully 50 ft. wide; then, on each side a good carriage roadway (which, in this instance, has the tramway along its inner edge), and beyond are the usual footways, also liberally wide. Each of these divisions is lined with rows of trees, and sometimes, as at Zaragoza, evergreen hedges are added. The effect is very agreeable. Of course, the amount of land necessary is rather extravagant, and where (as is generally the case in England) there is much cross traffic, the central footway would be too much intersected by crossings. But, for Spanish conditions, it is very suitable and good. It affords a curious contrast between the ancient and modern methods of resisting the heat of the climate. In this, foliage replaces the sheltering cornices and closely opposed walls by which the Moors and their contemporaries sought the necessary shade. And the airiness is, of course, much more salubrious. The "Rambla"—the older main thoroughfare of Barcelona—is also adorned with noticeable trees. They are splendid lofty planes, untrained and unlopped, except so far as is necessary for their proper care; and they show, I think, to great advantage over the conventional cones of foliage which are generally considered proper for town streets. A great number of the frontages on the "Paseo de Gracia" are already filled, and the remainder seem to be going fairly well.

The by-roads of Spain are simply as bad as they can be; sometimes spread over a hundred feet of ground, by the attempts of drivers to escape the mud or dust, and at others sunk deep in a cutting, formed by the repeated churnings of wheels and washings of trespassing rivulets. It is very true in Spain, the na-

tional proverb which says: "There is no short cut without labor."

The railways also are bad. One cannot even grant them the moderate approval which the high roads may claim. The country is often very difficult, calling for all the engineer's skill and ingenuity, and, as usual, in mountainous districts steep gradients, sharp curves, and long detours are necessary. Cuttings, even shallow ones, involve a large amount of blasting in the hardest rocks—granite, limestones, etc., or in treacherous soft sands, careful provision has to be made for the escape or diversion of the surface water. Embankments generally necessitate provisions of more magnitude than we are familiar with, for the stream in the traversed valley, which, although in summer almost a dry gravel-bed, is probably a powerful flood in winter and spring.

But, on the other hand, many of the Spanish railways traverse a country flat as the sea. In either circumstances, the ways and accessories are in bad condition. With very few and small exceptions they are single lines with loops at stations. Some few railways, however, have been constructed with tunnels, embankments, &c., of the necessary width for the second line of rails. The metals used are flat bottomed flanged, probably to avoid the detail labor consequent upon the use of chairs, &c. Sometimes even the hollow rail of ∩ section is used. And the road is worn and neglected till it attains almost its last stage of even comparative safety. Fortunately the maximum rate of speed is low. The stations, too, which are inconvenient and dirty, are placed at considerable distances from their towns. This appears to be, sometimes, merely an extraordinary freak, or a concession to the coach owners. Certainly it is intentional, for it is invariable, and often one passes the town quite near, and then has to return in one of the wretched little omnibuses from the distant station. There may be some better motive—the expected growth of the town, or some such unapparent reason. I hope so.

The rolling stock is also badly maintained, and often badly constructed. The engines are mostly of English or French make, and, I suppose, are good enough but are neglected. The carriages are nearly equal to the most inferior of English lines. Occasionally, of course, better specimens than this low average are met with.

The construction of new railways is, at present, I understand, principally carried on with French capital. Some of the latest sections opened are the following: Bobadilla to Grenada, Seville to Bobadilla (completing a direct route from Seville to Granada), Madrid to Talavera, and Lerida to Tarragona. Among the most important lines in progress are —from Vigo to Lugo and La Corunna; from Leon to Orense, meeting the last-named line; from Oviedo to Leon, Aranjuez to Cuenca, Seville to Huelva, and Seville to Badajoz. Parts of some of these lines are already finished and working, as before described, with connecting services of "diligencias."

There are also projects, shortly to be realized, of lines—from the present Cadiz line to the neighborhood of Gibralter, from Badajoz to Malpartida, from Vilalba (on the Madrid line) to Segovia, and a long line from Saragoza southwestward, parallel with the coast. A glance at the map will show that until these are complete the railways of Spain can hardly be called a system; and even then many large towns will only be indirectly connected by routes involving considerable detours.

Bridges are, in this country, frequent necessities. And the powerful action of nature and time enforce a certain standard of solidity and thoroughness. The greater number of the larger towns have their ancient bridges dating from the Mediæval or even the Roman epoch; well constructed originally and fairly well cared for now. Leon, Salamanca, Zamora, Toro, Valladolid, Avila, Toledo, Zaragoza, and Cordova have each one or more interesting old bridges over their respective rivers; most of them highly picturesque structures, with a fantastic variety of arches and piers and gate-houses—the result of many successive damages and repairs or partial reconstruction. That at Toro shows, too, a curious example of some of the difficulties to be contended with, in the erection and maintenance of such works. The bridge, which originally was, of course, about at right-angles with the direction of the stream, now appears, from some

points, to run parallel with it. The river has gradually changed its bed, by encroaching upon the soft soil of the left bank, necessitating the addition of more arches to the bridge; and then, again, an embankment wall of considerable length to protect the road and prevent the floods from severing the communication with the bank. And as the works are done very sparingly (it is not a rich community) the question is not decided, but only delayed. The river still persists at certain times in crossing over the road instead of under the bridge.

The new bridges occasionally seen are of similar character to those prevalent in the south of France; rounded piers with segmental arches — more useful than beautiful. But they are far better than the light, straight, ugly lattice girders which have been used at Lerida to replace part of the stone bridge recently destroyed. Two foot-bridges of similar inartistic iron construction have been thrown across the picturesque house-lined river at Gerona, sadly disfiguring the view of the stream. There are about the country a few examples of the cast-iron arch construction, which have a somewhat less offensive appearance. Not unfrequent in some less populated districts are light suspension bridges of wire, rope, and timber which have the advantages of cheapness both of material and construction, and are sufficient for their purpose.

In Madrid a miniature Holborn Valley, near the royal palace, has lately been provided with its iron viaduct, which is not, however, a work of any great magnitude.

In noticing railway bridges, I must first mention a smaller construction than what is usually termed a bridge. These are the lesser works for the occasional floods which sweep over certain plains—shallow broad sheets of water of insignificant power, perhaps—unopposed; but capable of great destruction if accumulated against such a dam as a railway embankment. Little height is necessary. The railway, elevated a few feet above the plain, is carried over a series of transverse stone piers, somewhat close together, with girders, or rather sleepers, to receive the metals. There is generally no floor. The bridges proper, by which the lines cross the large rivers, are nearly all the most simple, and similar lattice girders of rectangular outline (with the rails at the level of the bottom flanges), often of considerable span and frequently required to be much longer than the ordinary breadth of the stream, so as to accommodate exceptional states of the water. I must confess I was surprised at the lightness, almost, one might say flimsiness, of these structures, as compared with their spans and loads, and our usual notions of the relationship of these data. I have had an opportunity of learning that this economy is arranged by working out the usual formulæ with an unusually high coefficient of strength of the material. Notwithstanding this the material itself is of inferior quality, principally, I believe, Belgian. It is probable, however, that (as I noticed of timber-work in house-building) the fitting and jointing are carefully attended to, and thus the principal source of weakness, for which exorbitant "margins of safety" are usually allowed, may be to some extent curtailed. Indeed, it seems to me a question whether the generally prevalent extravagant allowance for defects is not over-reaching itself in becoming a direct encouragement to carelessness. I do not advocate exactly what I see here, the motive of which is undoubtedly economy; but still that object is attained and the trains pass and repass safely and regularly enough; possibly more so than if the engineers had known they had a big "margin for safety" to trifle with.

The piers to these bridges are of iron or stone, according to circumstances. If the former the same economy, of course, rules their proportions.

I saw in traveling in mountainous districts several examples deserving, I think, more attentive examination than the superficial one I was able to bestow upon them. The portions of lines between Burgos and Zaragoza (by Logroño) between Madrid and Avila, Alcazar and Cordova, and between Grenada and Bobadilla, I remember as being particularly interesting for their difficult engineering problems and solutions. At Madrid and Barcelona there are several lines of tramways through the main thoroughfares. They are worked with English cars, and probably owe more than this to English assistance.

Those at Barcelona are laid with a rather surprising disregard for the convenience of the non-traveling public. The lines in some cases pass along narrow streets where there is but about two feet breadth of footway, and so close to the curb that shop sunblinds, signboards, &c., are almost suppressed, and foot-passengers and inhabitants have to take refuge in doorways as the cars pass. This is more than inconvenient—it is dangerous. But it does not appear to be here considered the particularly selfish infringement of public rights which it undoubtedly would be in England. A section of the local press which protests against the whole system, probably goes too much to that extreme to gain any important influence, as the tram-cars are favorite means of transport. The lines are allowed to get into a very bad state of repair, too, but the vehicular traffic is not representative of so strong an interest as to make effectual protest against that evil.

Upon a line which runs out four or five miles northward to the suburbs in that direction, the service is worked by steam engines, which are of English make (Merryweather's, if I remember rightly). They draw trains of three cars each, upon lines laid at the edges of the road. These also are in bad order, and the high rate of speed used along the less-frequented sections of the road will probably, before long, end in an accident, and perhaps the condemnation of the whole system, when only the manner of working it is to blame. I traveled by this line, and watched the effect of the engine and cars upon the few horses we passed. I was pleased to be able to observe that only slight notice was accorded by them. It is likely that these animals had encountered the thing before, and no doubt many horses which will be alarmed at the first appearance of such a machine, will be reconciled to it more speedily than some of their masters. It appears strange that a distant and less busy land should be enjoying the benefits of our advanced science while we at home are so fettered by laws and restrained prejudices that even a trial of sufficient duration to be fair is impossible.

In harbor works the maritime towns show a desire to keep pace with the times; but I have, unfortunately, little information upon this subject. Barcelona is improving her accommodation for shipping by constructing an inner harbor, and Cadiz and Seville have a certain amount of such work in hand. But some of the other busy seaports did not come within my range.

I do not know of any late addition to the few canals of Spain. The same circumstances which I have described as making railway operations difficult have, of course, even more force against canals. The present canals, which I occasionally met with here and there, appeared to be as deserted of boats as are the rivers. But probably, later in the year, when the harvests and vintages have been got in, there is more occasion for their use. There can be no doubt that an extension of the canal system in the plains would be highly beneficial, if only for purposes of irrigation.

The rivers are distressingly neglected as far as navigation is concerned. Some of the larger ones, which are permanently well filled, are for many miles capable of being rendered navigable with only a moderate expenditure of capital and labor. Indeed, the question has long ago been discussed, and this fact admitted. And yet they are left to the dams and mills, with hardly a ferry boat upon the broad highways which ought to be arteries of commerce.

The ingenious, if not skillful, schemes of irrigation which prevail everywhere in this land of drought, deserve mention. The long sinuous channels and rough, yet carefully-regulated dams, of stones and mud have a certain set of principles and methods, the result of years of experience, which make their construction a little science. And the treatment of slopes and other difficult surfaces so as to render them amenable to this control, belongs to the same subject. But a detailed description is perhaps beyond the province of this paper.

The water supply to towns still leaves much improvement to be desired. The source is generally the river, and only in one or two instances is the filtration even tolerably effective. So that, although Spaniards drink a great deal of water, pure, or rather untempered, yet a glass of really good water is, in the lesser towns, a treat only occasionally enjoyed,

and more often the stranger drinks with dubious anticipation of the effects of the unaccustomed solution. The supply to the public fountains is fairly abundant in ordinary times, and the irksomeness of the necessary carriage is not felt as a hardship where nothing more convenient has ever been known. In seasons of drought, however, there is sometimes serious suffering arising from the scarcity or badness of water.

The lighting of towns is fairly well done, allowance being made for the absence of gas, which only the capital and a few other favored cities can boast. The lamps are fed with petroleum, and I notice an extensive and growing appreciation of this fluid for domestic as well as public purposes..

The police administration is related to rather than connected with these subjects; but I must note the interesting fact that every town (except, I think, Madrid) has still its ancient service of watchmen, who patrol the streets, armed with spear and lantern, and chant the time o'night and the state of the weather, embellishing the cry sometimes with a pious ejaculation. There is something charmingly out of date about all this.

Of buildings which deserve to rank as public works, there are, I fear, but few examples of late erection to be enumerated. The national pastime, bull-fighting, despite all the talking of its discouragement, has yet vitality enough to demand and obtain substantial new theaters. These are highly interesting structures, partly on account of the many points in which they resemble the ancient Roman amphitheater. The new "Plaza de Toros," at Madrid, is a vast open amphitheater of granite steps, encircling the arena and its ring passageway, and surmounted by the two-storied covered structure which contains the higher class of seats, and under which are the passages and corridors. The inclosing wall is in a kind of modernized Moresque style.

There are, in different towns, a few administrative buildings and theaters, barracks, &c., of no particular note. The exterior of a new theater in the "Paseo de Gracia" before mentioned (Teatro Español), deserves note for its good adaptation of Moresque architecture to modern street purposes. It has a façade in two blocks of similar and symmetrical design, with the entrance gateway and passage between them. The detail is generally very agreeable, although not quite pure. The interior of the theater itself is not particularly good or novel.

Of churches, ancient towns have inherited a sufficiency for the wants of to-day; for where progress and increase of population are active, heresy and scepticism are also rife in a more than proportionate degree—so that often fewer rather than more churches are required. Barcelona, with its 300,000 souls, has not so many churches as some old towns of 10,000.

Schools, museums and hospitals are generally accommodated in ancient buildings, either built for those purposes, or afterwards appropriated to them. In these departments of civilization there are not many signs of activity, although there is a knowledge extending that something more is wanted.

In submitting these traveler's notes to the readers of the *Building News*, I must make some apology for their short comings. I do not pretend that they are exhaustive. There are several important cities of Spain of which I saw nothing. And they are, perhaps, not altogether free from occasional error, as those things which I have noticed I have to write of inconveniently, and without even a guide-book to represent the literary aids which one generally has at command. Perhaps these circumstances may be urged against the criticism I should otherwise deserve.

ENGINEERING STRUCTURES.

PROPOSED TUNNEL UNDER THE ENGLISH CHANNEL.—An excursion was made a few days ago by M. Léon and M. Varroy, the Minister of Public Works, accompanied by M. Ribot, deputy, and Fernand Raoul-Duval, civil engineer, to Sangatte, near Calais, for the purpose of visiting the soundings which have been undertaken by the Submarine Tunnel Company between England and France. The excavations have been commenced at some distance from the village, at a spot where the cliffs have an altitude of 70 ft. above the level of the sea at high water. A point has been chosen where the rocks of gray chalk which have to be traversed by the tunnel come to show their heads at the surface of the soil. On the opposite shore similar borings have been, as is known, begun, so that the works are proceeding simultaneously.

The soundings that have been made during the last few years demonstrate that the base of the Channel consists of a compact mass of chalk, resting on banks of slate. This mass, which is easy enough to pierce, is said at the same time to sufficiently resist infiltration. It would, therefore, present a substance excellently adapted for perforation. But what yet remains to be proved is, whether the succession of these chalk layers will not disclose some irregularities or ruptures which would render the enterprise impossible. That is why, before commencing the definitive works, it was necessary to make an attentive study of the ground by means of trial excavations. It is now five years since the company which had obtained the concession for the tunnel began the first borings at Sangatte. But only since last year have the works been prosecuted with any activity.

The chairman of the company was originally M. Michel Chevalier, but since his decease the place of the great economist has been taken by M. Léon Say. The period allotted for the trials was not to have exceeded five years; but as, according to the terms of the concession, the Government was authorized to prolong this term by three years, the Minister of Public Works did not hesitate to accord this extension. However, before making a formal engagement, M. Varroy wished to examine for himself what had been done. The shaft has now reached a depth of nearly 200 feet, or about 130 feet below the level of high water. It has a width of 10 feet, and is lined with oak, so that the water cannot penetrate very freely—not more than 17 gallons a minute. This water is not salt, which is thought to prove that the layers hitherto traversed have their point of contact sufficiently far from the shore to prevent the sea from ascending the shaft. It is intended to sink to a depth of 300 feet, and then a gallery will be excavated in the direction of England. Up to the present the engineers are highly satisfied with the results obtained, as no irregularities have been discovered, which is considered a good augury for the success of the enterprise.

Unfortunately, with the greatest exertions on the part of the engineers, it is impossible to proceed at a quicker rate than twenty inches a day. Nevertheless, in eighteen months or two years enough progress will have been made to arrive at a perfect understanding about the possibility of the undertaking. It is stated that the work will not fail through lack of funds.

THE FORTH BRIDGE.—As we have already announced, it has been decided to abandon the construction of the Forth Bridge. This is not a matter for surprise. But the directors of the companies concerned, namely, the North British, the Great Northern, the Midland, and the North-Eastern, will now have to answer certain questions and give certain explanations to their shareholders. The history of the undertaking has yet to be written, and must be made public. Considerable sums have been already wasted over the scheme, and there is reason to believe that much money remains to be paid. So far as the facts can be ascertained, it seems that when the last design was prepared by Sir Thomas Bouch, no money could be obtained from the public to carry out the scheme, because some competent firms of bridge-building engineers would not take the contract for carrying out Sir Thomas Bouch's design, and those who were not unwilling to tender pointed out that there was no capital subscribed. Thus the matter stood in such a position that the public would not take shares because there were no contractors; and engineers would not tender, some of them because they condemned the design, and others because there was no capital subscribed. It was generally considered that the whole thing had fallen to the ground, when it was suddenly announced that Messrs. Arrol and Co. had taken the contract. Now Messrs. Arrol and Co. are a highly respectable and competent firm, but it does not appear that they had ever carried out a really large contract for bridge work, and that they should have awarded to them a contract for such an enormous bridge as that proposed by Sir Thomas Bouch caused some surprise. No one asserts—we ourselves least of all—that Messrs. Arrol could not have built the bridge if it could be built at all. But a great many men of much more experience asserted that the design was wholly impracticable, and it would in the fitness of things have been more satisfactory had some firm of great experience in the erection of large bridges undertaken the work. It is now stated that the scheme has been abandoned, but the question arises, what will Messrs. Arrol and the other contractors have to say on this subject? Rumor asserts that Messrs. Arrol will receive a sum of £20,000 by way of penalty for the failure of the company to carry out the undertaking. Whether this is true or not will be asked by the shareholders, and must be answered by the directors. Again, if the design for the bridge was quite satisfactory, and the terms of the contract all that could be desired, why is it that the scheme has not been proceeded with? The fall of the Tay Bridge has very little to do with the matter. The reason argued by the directors for the abandonment of the scheme is not convincing. In one word the whole matter requires careful investigation, and a detailed account of all the circumstances and of the progress of events should be made public.

THE TRANS-RUSSIAN CANAL.—A correspondent of the *Newcastle Daily Chronicle*, alluding to the canals which unite the Vistula and Dneister, writes: "It may interest your readers to know that, eighteen or nineteen years ago, when Warsaw was still unsettled after the revolution of 1861, Messrs. Wigham, Richardson and Co., of Low Walker, built a small paddle steamer for service in the river Dneiper, in the neighborhood of Kieva. This little steamer was of extremely light draught; in fact she only drew 17 inches. As there was considerable difficulty about insuring such a craft, a member of the firm went with her from the Tyne, across the North Sea and the Baltic, up the river Vistula as far as Warsaw. He

left the steamer at Warsaw, and she afterwards dropped down the stream as far as the entrance of the river Bug, which she ascended and passed through the canal which is cut through that huge marsh land—the spongy reservoir whence all these great rivers flow. He found the navigation of the Vistula itself for 400 or 500 miles between Danzig and Warsaw exceedingly difficult even with an experienced pilot; and although they drew only 17 inches of water they repeatedly run aground." The writer of the letter we are quoting from adds that while he does not pretend to any special knowledge in such matters, with the exception of the rafts of timber which are floated down the stream, and the barges which convey the corn which grows on the banks of the Vistula to Danzig, he cannot conceive that any traffic could be carried on on this river, and certainly none in competition with railways. Count Zamoyski tried several steamers, but they always got snagged or stranded on the shifting sandbanks and the enterprise was a complete failure.

A LARGE undertaking has recently been completed in Russia, in the shape of a long railway bridge over the Volga, on the Syoran and Orenberg Railway, connecting the cities of Syoran, in the government of Simbrisk, with that of Samara. The width of the river is nearly a mile, and as it is liable to the occurrence of very heavy spring floods, the piers—of which there are fourteen altogether—had to be built 100 feet above mean water level, the depth of the river being more than 50 feet. The girders, 364 feet long and 20 feet wide, were all riveted and put together on the right bank of the river, and then floated to their position. The whole cost of the bridge was 7,000,000 silver roubles, and it is worthy of mention that it was completed without any loss of life or any accident of importance.

THE engineers of the St. Gothard tunnel are stated to be in a fair way to overcome the difficulty arising from the falling in of the roof in the part known as the "windy stretch." This stretch, which is 200 meters long, and situated almost directly under the plain of Andermatt, passes through strata composed alternately of gypsum and aluminous and calcareous schists, which absorb moisture like a sponge and swell on exposure to the atmosphere. It has given the contractors immense trouble, and has fallen in so often that it was seriously proposed a short time ago to allow it to collapse, and make a bend so as to avoid the "windy stretch" altogether. The expedient now adopted, which has so far been successful, is the rebuilding of the supporting masonry in rings of solid granite. The rings are each four meters long, so that in the event of any one of them giving away the others will not thereby be affected. The building is constructed slowly and with the utmost care; no imperfect stones are allowed to be used; the masonry is perfect, and the walls of extraordinary thickness—in the parts most exposed to pressure not less than ten feet. At the beginning of June only 34 metres of the "windy stretch" required to be revaulted.

THE average yearly cost of maintenance of roads in France has recently been given as about 31,000,000f.—£1,240,000—for 37,000 kilometers of national roads, 20,000,000f. for 41,000 kilometers—22,940 miles—of departmental roads, and 75,000,000f. for 260,000 kilometers of parochial roads, without counting bridges or large rectifications. The cost price of materials varies considerably in different departments, according to the means of access to resistant rocks. On an average it is 6f. 70c. the cubic meter for the whole of France, but it descends to 3f. to 4f. in the mountainous regions, such as the Alps, L'Ardèche, L'Isère: and it rises to 11f., 13f., and even 14f. in the plain country, as in Seine-et-Oise, La Marne, and L'Aube. The wear is nearly proportional to the number of vehicles passing over the roads; in L'Ardèche it is about double what it is in L'Aveyron, and in L'Hérault it is about four times as much with equal quality of materials. The statistics further show that, per kilometer and per 100 draught-horses, the mean consumption of "metalling" is about 23 cubic meters annually. It is calculated by some engineers that to keep the roads in a thoroughly good condition this proportion should be increased to 28 cubic meters, with an additional expenditure of nearly 3,000,000f. As matters stand the consumption of road metal is about 1,326,000 cubic meters on the national roads. All this is bruised, and reduced to mud and dust every year by the wheels of vehicles and the hoofs of horses. Accumulated in a single heap, it would form a tower 130 meters in diameter and 100 meters in height. Equally spread over the whole surface of the national roads of France, it corresponds to an average wearing out of 9 mm. thickness.

LONDON BRIDGES.—It will be a surprise to most people, remarks the *Echo*, to learn that, after paying £1,373,325 to free the toll bridges over the Thames, the Metropolitan Board of Works finds the bridges in such a condition as to require the expenditure of £640,000 to make them safe. Yet this is what transpired at the meeting of the Board last Friday. It is no answer to the cry of disappointment that is certain to arise to say that the expenditure will be spread over a number of years; it will have to be borne by the ratepayers, whether it is one year or twenty. Sir Joseph Bazalgette, the engineer, has presented an elaborate report, in which he describes the condition of the nine bridges (excluding that at Deptford), which demand the enormous expenditure we have named. Two of them—namely, Battersea and Putney—will have to be rebuilt, the former at a cost of £250,000, and the latter with the approaches costing £300,000. The case of Waterloo Bridge is the most curious. Soundings which have been made of the bed of the Thames since 1823, when the celebrated architect of the Menai Suspension Bridge, Telford, took the soundings, have established that the scour is continually deepening the bed of the river. Waterloo Bridge was built in 1814, upon a timber staging resting upon piles 20ft. long, and the masonry was carried to a depth of 5 feet below the bed of the river. The result

of the scour has been that the heads of these piles are now from 1 foot to 6 feet above the bed of the river, and are visible at low water. If the foundation between the piles should be washed out, the structure would inevitably sink. The engineer now proposes to put wrought-iron cylinders round each pier, and to fill up to the level of the foundations, so as to make a solid foundation right down to the piles. These works are estimated to cost £40,000, and they were ordered on Friday by the Board. Vauxhall Bridge is in pretty much the same condition, and here it is proposed to convert the three central arches into one opening, and to dredge out, so as to get an adequate area of waterway, besides putting down similar caissons to those recommended for Waterloo; estimated cost £45,000. The Lambeth Bridge is decaying; from 5 feet of the cable 9lbs. weight of rust has been removed, of which about 42 per cent. was pure iron. The Albert Suspension Bridge, "if loaded on one side, will depress where loaded, and rise where not loaded." A part of Battersea Bridge overhangs as much as 9 feet, and the stumps of the piles are in a ruinous condition. Wandsworth Bridge has suffered from want of cleaning and painting. Putney Bridge, which is 151 years old, is in little better condition than Battersea, and is a serious obstruction to the navigation. Of Hammersmith Bridge it is remarked that it will become a matter for serious consideration whether wrought-iron should not be substituted for the cast-iron cross-girders under the roadway. The Board have resolved to seek Parliamentary powers for such portions of the foregoing projects as they have not power at the present to carry out, and for mending this bad bargain of the Board the ratepayers will have to pay what will be equal to a single rate of 6½d. in the pound.

IRON AND STEEL NOTES.

CAST-STEEL RAILS.—On the Upper Silesian railways cast-steel rails have been in use for a number of years, and for the Kattowitz district, Inspector Theune has published the statistics of rails which have broken during the last six years. There are in all 102 miles in his district, 84 miles of which are situated in open dry land, while 18 miles are in forests, constantly retaining moisture in the ground. The sleepers are of oak, the rails 5 in. high with a broad base and partly laid with the joints on the sleepers, partly with suspended joints. There were in all 329 broken rails during the six years' period of observation, and of these breakages 207 or 2.4 per mile occurred in the dry part of the line, and 122 or 6.8 per mile in the forest district. The fractures were distributed over different quarters of the year as follows:

First three months in the year			216
Second	"	"	28
Third	"	"	14
Fourth	"	"	71
			329

During the first year after laying the line, the number of broken rails was very small, most of the rails having in fact been down for eight or ten years before fracture, and the average age of a broken rail being 7.5 years. During this time about 23 million tons passed over the line. The rails are notched and drilled; 73 broke through the solid section, 51 through notches, and 205 through fishbolt holes, showing in but a minority of cases any old flaw or crack. The 73 cases of breaking through the full section, the compiler of these results regards as due to the unequal tension given to the rails in the rail-straightening machine. The 51 cases of fracture through notches are mainly caused by the sudden change in section, and not, Inspector Theune asserts, by the rail being injured in notching it, since in hardly any cases were old cracks discovered. Of the 207 breaks through fishbolt holes, 8 per mile occurred on solid fish joints, and only 1.36 on suspended fish joints. This is a very large percentage in favor of suspended joints, even taking into consideration that all the supported joints were older. It should be mentioned that the fish-plates were iron, and not like the rails of steel.

PURIFYING FUSED IRON AND STEEL.—For the removal of phosphorus, sulphur, silicon, or other impurities from fused iron and steel, Mr. Ludwig Merlet, of Vienna, Austria, proposes to blow into the liquid metal alkalis, or carbonates of alkalis, or dolomite, or caustic lime, each separately; or a mixture of these or some of these materials, or each or mixtures of some or all of them combined with chloride of sodium, or nitrate of soda, sesquioxide or protoxide of iron, or cinders of oxidulated iron, or combined with a mixture of some or all of these materials, with or without addition of black wad or pyrolusite in a powdered state. Or, according to another mode of procedure, he mixes the liquid metals with alkalis, or carbonates of alkalis, or carbonate of lime, or caustic lime, or dolomite, each separately; or mixtures of these, or some of these, materials, or with a combination of one, or more, or all of these materials with chloride of sodium, or with nitrate of soda, or with both; and in combination or not with black wad or pyrolusite: or he mixes up the liquid metal with alkalis or carbonates of alkalis, each separately, or a mixture of them, or with a combination of one or more of them, or all of them, with chloride of sodium, or nitrate of soda, or with both, and in combination or not with black wad or pyrolusite.

THE FUTURE OF THE PUDDLING AND BESSEMER PROCESSES.—The well known Austrian metallurgist, Professor Von Tunner, in concluding the report of the Austrian official commission on the Thomas-Gilchrist process, expresses his own views on the future of puddling as follows: "Of great importance is the fact that by the Thomas dephosphorization process, the Bessemer converter is no longer, as formerly, confined to the treatment of pig-iron free from phosphorus, but is now available for nearly every kind of pig. It is clear

that the Bessemer, will in the immediate future become the prevailing process everywhere for the production of malleable iron, as it is now for steel. The extinction of puddling works, especially all of those which are occupied with the production of weld iron, is, by the increase of the production of ingot iron by the Thomas method, imminent. The producers of weld iron may indeed still think they have some comfort in the belief that ingot iron cannot be readily welded, but the fact is that we have now excellent ingot iron, nearly as easy to weld as puddled iron, and it will in all probability not be long before the point whether ingot iron is really any more difficult to weld than puddled iron comes into question. Exactly the same occurred at the introduction of the puddling process in place of the refinery hearth. It is therefore greatly to be feared that the solitary hope of puddling forge owners will be soon disappointed. Moreover, the small measure of protection which the Thomas patent royalty extends at present to the puddling works must cease in a specified time. With the exception of some puddling furnaces and fineries in special localities it may be asserted that for the manufacture of malleable iron, especially of the highest qualities, the Siemens-Martin process alone can possibly compete with the Bessemer.

RAILWAY NOTES.

An electrical railway has been established in the Gardens of the Brussels Exhibition, and is working all day long with perfect regularity. The number of wagons is three, each of them carrying six passengers, with a velocity, it is stated, of 3 meters per second, or about 6.7 miles per hour, to a distance of 3000 meters for 3*d*. The locomotive, of which the weight is 800 kilogs., carries a Gramme machine, worked by another machine, which is stationary.

Against the extensive railway project under consideration in South Africa, the reported opposition was of that sort that comes from the fact that each locality was favorable to the part of the scheme which was favorable to itself, and opposed to others. Hence an intolerable load of amendments and much controversy. It was, however, resolved that the border line should be extended from Queenstown to Aliwal North, *via* Dordrecht instead of *via* Burghersdorp, and that the line from Beaufort West should be extended *via* Victoria West to Hope Town.

The *Journal Officiel* gives the total length of secondary railways at work in France as 2207 kilometers, at the end of March last, or 225 kilometers more than last year. The 225 kilometers opened last year are as follows: Clermont to the Bois de Lihus, 16 kil.; Beaumont Persan to Hermes, 18 kil.; Velu-Beatincourt to Saint Quentin, 46 kil.; Lille to Valenciennes and extensions, 40 kil.; Crécy-Mortiers to La Fère, 8 kil.; chemins de la Meuse, 21 kil.; Remiremont to Cornimont, 24 kil.; Mézidon to Dives, 29 kil.; Miramas to Port-de-Bouc, 11 kil.; Marlieux to Châtillon, 12 kil.

The Jubilee of Railways in England.—It may be interesting just now to note that it was exactly fifty years ago on Wednesday since the first really grand work in the shape of an English railway was opened, and the first railway accident upon record took place. The line ran between Liverpool and Manchester, 31 miles in length, having been begun in 1826. The opening was attended by the Duke of Wellington, Sir Robert Peel, Mr. Huskisson, and other well-known public men. The famous "Rocket" engine was one of those used on the occasion, and it was this machine which caused the death of Mr. Huskisson.

Railways (Continuous Brakes).—A second return, presented to Parliament in pursuance of the Railway Returns (Continuous Brakes) Act, 1879, shows the amount and description of continuous brake power in use on passsenger trains on the railways in the United Kingdom for the six months ending June 30 last. The total amount of stock returned as fitted with continuous brakes to June 30, 1880, is—of engines, 1,340, or 27 per cent., and 14,872 carriages, or 36 per cent Of the engines only 931 have the brakes applied to the wheels; and included in the number of carriages there are 652, and 1,768 other vehicles fitted only with chains or pipes and connections for connecting the brake. During the six months ending June 30, 1880, the amount of stock fitted with continuous brakes is 228 engines, or 4 per cent., and 1,587 carriages, or 4 per cent. The stock not fitted with continuous brakes numbers 3,574 engines and 26,140 carriages. The rejoinders of the several railway companies to the Board of Trade circular with regard to the adoption of continuous brakes have also been issued. The manager of the London and North-Western states that his directors would not have been justified in the earlier adoption of any system of brake without considerable experience of its use, but they now believe that the brake they have decided to adopt complies with the requisite conditions, and no time will be lost in extending its use to the whole of the carriage stock of the company. The Midland Company state that they have caused nearly all the fast passenger trains to be fitted with continuous brakes which satisfy the Board of Trade requirements, but the directors do not feel justified in giving the undertaking suggested in the Board of Trade circular. The Great Northern manager argues that the immediate general adoption of any one of the forms of automatic brakes known would not attain the end the Board have in view, but ere long experience will lead to the production and use of a simple and effective brake, satisfactory to the Board and to the public, as well as to the companies. The London, Chatham, and Dover decline to commit themselves to the expense of adopting any one system, which might and probably would be immediately superseded by a better.

From the general report of the Board of Trade upon the accidents of the railways in the United Kingdom in 1879, it appears that of the total number of persons returned to the

Board of Trade as having been killed in the working of railways during the year was 1032, and the number of injured 3513. Of these, 160 persons killed and 1307 persons injured were passengers. Of the remainder, 442 killed and 1951 injured were servants of the companies or contractors; and 420 killed and 255 injured were trespassers and suicides and persons who met with accidents at level crossings or from miscellaneous causes. Of the passengers, 75 were killed (including 73 supposed to have been lost in the Tay Bridge disaster) and 602 were injured from accidents to trains. In addition to the above, the companies have returned 42 persons killed and 2314 injured from accidents which occurred on their premises, but in which the movement of vehicles on railways was not concerned. The total number of passenger journeys, exclusive of journeys by season ticket-holders, was 562,732,890 for 1879, or 2,291,565 less than in 1878. The proportions of passengers killed and injured in 1879 from all causes were, in round numbers, one in 3,517,000 killed and one in 430,000 injured. In 1878 the proportions were one in 4,520,000 killed and one in 322,000 injured. The proportions of passengers killed and injured from causes beyond their own control was, in 1879, one in 7,503,000 killed and one 934,700 inured; but if the Tay Bridge disaster is excluded from the computation, the proportion killed would only be one in 281,366,500, or less than in any year on record. In 1878 the proportion was one in 23,540,000 killed and one in 481,600 injured. Excluding ten injuries under the head of miscellaneous, 101 train accidents have been inquired into and reported on by officers of the Board of Trade in 1879, as against 108 for 1878. The report considers the year satisfactory on the whole, but concludes with a hope that a complete adoption of the block and interlocking systems, of continuous footboards with proper platforms, and especially of improved brake-power will no longer be delayed.

ORDNANCE AND NAVAL.

THE NEW BREECH-LOADING FIELD GUNS. The first battery of breech-loading guns, designed for the use of the Royal Horse Artillery and Field Brigades, was issued for service from the Royal Gun Factories, Woolwich, last week, having first been inspected and passed. They will in the first place be sent to Exeter and placed in charge of F Battery, B Brigade, Royal Horse Artillery, for the purpose of testing their efficiency by a series of rough work at Oakhampton, in competition with muzze-loaders, the test being irrespective of power and accuracy which have been already established at Shoeburyness, but designed to ascertain the suitability of the new weapons for the knocking about amidst dust and mud and bad weather which they must expect on active service. Should they pass through the trial with satisfaction, they will probably be transferred for more extended duty and under other conditions to G Battery of the same brigade. The guns have been constructed as far as practicable, seeing that they are breech-loaders, on the model of the muzzle-loading 13-pounder, which is the most highly regarded specimen of British ordnance, but are somewhat longer by reason of the breech arrangement. Both are of 3-inch caliber in the bore, which is in each 34 inches long, and enlarged to 6½ inches in the powder chamber, but while the muzzle-loader was regarded as of an extreme length at 7 feet 4½ inches, the breech-loader measures over all no less than 7 feet 7¾ inches, and looks a very slender cannon indeed. The apparatus at the breech is extremely simple, and no less effective. A turn of a lever unlocks the breech-piece, which when withdrawn, is seen to be a solid drum of metal, about 10 lbs. in weight, which screws into the gun by a thread surrounding the whole cylinder except at intervals where horizontal ways are smoothly cut, so that the drum can be readily drawn out when in position to clear to retaining jambs. A half turn of the screw thus releases it in a second, and being received by a carrier, it swings round on a hinge to the right, leaving the open breech clear for loading. Before this takes place a tube is inserted to protect the screw and ease the way, and through this tube the elongated projectile and cartridge are passed, when the breech-block is swung back, run home, and screwed fast by the locking lever in less time than it takes to describe the operation. Much ingenuity has been expended in obviating the possible danger of firing the gun before the breech is properly closed, which was the great drawback of the old breech-loaders, and four separate devices will be tried with this object. Three of the guns are fitted with a slide which covers the vent and cannot be removed until the breech is locked, when it may be drawn back by the gunner, and the three others have different contrivances for doing the same thing automatically and placing the safety slide beyond the gunner's control. The fittings are of bronze, formerly called gun-metal, but the metal of the gun is chiefly steel. The whole of the chase or barrel is of steel, and it is only in rear, where the greatest strain of explosion takes effect, that wrought-iron coils are shrunk on to strengthen and support it. The lightness of the gun, which weighs only 8¾ cwt., may be mainly ascribed to the employment of the material, and a concession is at once made to the advocates beth of steel and breech-loaders.

RANGE FINDING.—Lieutenant Edwards, R. A., has recently called attention to the question of range finding by two papers which he has contributed to the Artillery Institution. The importance of this subject is such that a short notice of the present position of the question is desirable. The value of finding the range by instrument in preference to depending on trial shots was recognized by the committee at Oakhampton in 1875, who recommended that range finders should be issued to batteries, and that additional men and horses should be provided to enable the service to be effectually performed. Any one acquainted with the service would know that if this recommendation

was carried out it would prove that times were indeed changed. The great difficulty that has always beset and hampered the efficiency of artillery, especially in the field, is the difficulty in impressing the difference between hitting and missing. Few really recognize that the material effect of a magnificent troop of horse artillery depends on the actual number of hits they make in action; that all the proficiency displayed in riding and drilling, all the smartness in turning out with well-fitted harness, all the science expended in the construction of guns and carriages, shells and fuses, are only valuable as tending directly or indirectly to one end, and that six well-intentioned but unskillful men may frustrate the object for which a battery has existed from its first formation in the course of a few hours, for many batteries have continued for many years and only been in action on a few occasions. In the Crimea a competition trial was instituted by General Codrington between our own field artillery and that of the French. Before coming into action the contrast in the appearance of the English and French batteries was very great In fact the latter appeared to be so sensible of it that they seemed to try to keep at a distance so as to avoid comparison. From the moment the firing began, however, the tables were turned, for the French scored exactly two shots on each target to each single English one. The French, it turned out, had a skilled marksman at each gun. On one occasion the English had a general, a colonel, and a lieutenant at one gun, who were all distinguished officers, but who had not the special skill of their French competitor. Unquestionably the inferiority made manifest in target practice would tell in action, though without its being possible to estimate it. What actually resulted after Oakhampton was that batteries have been supplied with range finders, but no extra men have been allowed and instruction has been left very much to chance. Now the question needs to be grasped and carried out consistently with a distinct object to be effectually dealt with. If it is determined to have an accurate and high-classed instrument, then a supply of men specially skilled to its use must be secured. If this cannot be allowed there seems no intelligent alternative but to have a simple and comparatively inaccurate instrument, for any benefit due to the accuracy of the instrument is certainly dependent on that of the man using it. A beautifully correct instrument pointed incorrectly is obviously an anomaly; for while it cannot benefit the user by its powers it troubles him by its complication. It should be decided by special experiments what can be achieved by each instrument, and at the cost of what application of time and men, and then suitable provision should be made for the full mastery of whatever one was adopted. Lieut. Edwards enumerates many, among them some which could not long be seriously contemplated, such as Elliott's telescope, the pocket sextant, and the prismatic compass. Some of his objections, however, are, we think, hardly reasonable. For example, he twice objects to instruments having a fixed base a yard long, as liable to be bent. The same objection might be urged against the rifle barrel of every infantryman. The principal instruments to be noticed are Nolan's, Watkins', Berdon's, and certain instruments of Edwards' and Weldon's. Of these Weldon's and one or two of Edwards' are the simplest. As to accuracy, there is little difficulty with the best instruments if the men are trained. Watkins' has the advantage of requiring only two men to use it, which can be done before the battery comes into action. Nolan uses the gun as a stand, which gives great steadiness, but slightly delays the first rounds. On the other hand, it might happen that men sent on in advance of the battery might mistake the point on which the commanding officer might decide to open fire in actual service, though in target practice no such doubt might arise. Lieut. Edwards, after discussing the present very imperfect system of instruction, suggests that an instruction center is needed, and an officer and staff of non-commissioned officers appointed, indicating that Aldershot is the best station for the purpose. We do not think that such a branch of instruction, however, ought to be separated from the school of gunnery. Perhaps the work might have to be chiefly carried out at Aldershot, both because practice over broken ground is necessary, and because a considerable force of field artillery is always there; but we think that any instructing officers ought to report to the School of Gunnery, and be available to work there at times—for instance, when the Artillery auxiliary forces are there assembled. A small independent department such as Lieut. Edwards contemplates provokes continual jealousy and opposition.

BOOK NOTICES.

Publications Received.

Bulletin of the Philosophical Society of Washington, Vols. 1, 2 and 3.

Monthly Report of the Meteorological Bureau for September.

Manufacture of Charcoal in Kilns. By T. Eggleston, Ph. D.

Parting Gold and Silver in California. By T. Eggleston, Ph. D.

By courtesy of Mr. James Forrest we have received late paper of The Institution of Civil Engineers.

Small Motive Power. By Henry Selby Hele Shaw.

Researches on Explosives. No. 2—Fired Gunpowder. By Captain Noble, F.R.A.S.; F.C.S., and F. A. Abel, C. B.; F.R.S. London: Trübner & Co.

This quarto pamphlet is reprinted from the Philosophical Transactions of the Royal Society. It deals with one line of researches only, viz.: fired gunpowder. But this is by no means so simple a subject as might at first be inferred.

The chemical salts formed; the heat generated; volumes of permanent gases generated; pressures; actual temperatures of explosion; position of the shot when combustion is com-

pleted; total work performed in a gun tried, are a few of the leading topics discussed.

The results of trials and calculations are carefully tabulated.

SCIENTIFIC LECTURES. By SIR JOHN LUBBOCK, Bart. London: Macmillan & Co.

A series of lectures by this eminent investigator is a welcome addition to literature of popular science. The writer's work is altogether a labor of love, but it is nevertheless as siduous and careful.

The topics of the present series are: 1st. On Flowers and Insects. 2d. On plants and Insects. 3d and 4th. On the Habits of Ants. 5th. Introduction to the study of Prehistoric Archæology.

The typography and illustrations of the book are exceedingly good.

ALPHABETICAL MANUAL OF BLOWPIPE ANALYSIS. By LIEUT.-COL. W. A. ROSS. London: Trübner & Co.

The author of this work is known to blowpipe students by his larger work on "Pyrology."

In many respects the present manual is convenient. The reagents, reactions, implements used, and assays are arranged and fully treated in alphabetical order. It is therefore better adapted as a reference book to the needs of the practical worker than as an instruction book for the learner.

It is well printed, and illustrated with considerable fullness.

AN INTRODUCTION TO PHARMACEUTICAL AND MEDICAL CHEMISTRY. By Dr. JOHN MUTER, F.C.S. Second Edition. Philadelphia: Presley Blakiston.

This voluminous treatise is divided into two distinct parts, the first being theoretical and descriptive, and the second practical and analytical.

The first part treats with much fullness of elements and their compounds, with reference to their uses in medicine. The second part is quite a complete treatise on wet analysis, both qualitative and quantitative.

A limited space is devoted to the examination of medicinal preparations.

The work is large, and although without illustrations, seems to be a good compendium for the medical student.

MISCELLANEOUS

A DIFFUSIVE LANTERN.—The globes of opal and ground glass used in connection with the Jablochkoff candle and other electric lights have considerable diffusive power; but it is a drawback to their employment that they absorb from 30 to 50 per cent. of the total light produced in the arc. M. Clemandot appears to have found a better mode of spreading the illumination in forming the lantern of a double glass envelope stuffed with glass wool, spun by a peculiar process, so as to yield fibres 175 times finer than a human hair, and 45 times finer than the finest cocoon silk. The first public trial of M. Clemandot's lantern was recently made at the Magazins du Louvre, Paris. A globular form of lamp was originally tried; but it was found that dust got into the wool and soiled it, so that a new shape had to be devised. This proved highly successful. The transparent part of the lantern is conical in shape and tapers downwards. The walls are made of united glass tubes, like Pandean pipes, each filled with glass wool, and closed at top and bottom to exclude dust. Not more than 15 per cent. of the total light is absorbed by this process; the opacity can be varied at will by introducing less or more wool into the tubes; and the light can be tinted any desired color, either by the stain given to the spun glass, or the tubes which build up the wall of the lantern.

CONVENTIONAL SIGNS FOR WEIGHTS AND MEASURES.—The International Committee of Weights, sitting at Paris, has decided upon a system of conventional signs for expressing decimal weights and measures, as initiated by the Swiss Government, and more recently approved by the Government of Italy, which has expressed its intention of using all its efforts to obtain the universal adoption of these signs.

The *Bulletin du Ministere des Travaux Publics* has notified its intention, in common with some other French publications, of using the same symbols, which are as follows:

Measures of Length.

Kilometer	km.
Meter	m.
Decimeter	dm.
Centimeter	cm.
Millimeter	mm.
Mikron (0.001 mm.)	μ

Superficial Measure.

Square kilometer	km^2.
Hectare	ha.
Are	a.
Square meter	m^2.
Square decimeter	dm^2.
Square centimeter	cm^2.
Square millimeter	mm^2.

Cubic Measure.

Cubic meter	m^3.
Stère	s.
Cube decimeter	dm^3.
Cube centimeter	cm^3.
Cube millimeter	mm^3.

Liquid Measure.

Hectoliter	hl.
Décoliter	dal.
Liter	l.
Déciliter	dl.
Centiliter	cl.

Weight.

Ton	t.
Metric quintal	q.
Kilogramme	kg.
Gramme	g.
Decigramme	dg.
Centigramme	cg.
Milligramme	mg.

The adoption of a common system of abbreviations wherever metric measures and weights are employed possesses many obvious advant-

ages, but it requires to be known in order to prevent confusion.

MR. J. IRELAND, well known in connection with improvements in iron foundry, cupolas, furnaces, and other plant, has, we are informed, established a small experimental works at Edward street, Broughton lane, Manchester, in which trial samples of cast iron, wrought iron, steel, spiegeleisen, or ferro-manganese, can be made direct from the ore in any quantity from one pound to one ton. Even after the discovery of what may be valuable material, great difficulty has often been found in getting iron-makers to smelt a small quantity for trial, and development of mineral fields has been thus postponed, and it will no doubt be of service to many to be able to obtain a sample product, on a large scale, of any mineral; and should there be fuel, limestone, and fire-clay found along with or in proximity to the ore, the samples of metal can be made with those materials if they are found suitable for the purpose.

SILVERING BY COLD RUBBING.—Make paste by thoroughly grinding in a porcelain mortar, out of the light,

Water	3 to 5 oz.
Chloride of silver	7 oz.
Potassium oxalate	10½ oz.
Salt (common table)	15 oz.
Sal ammoniac	3¾ oz.

Or,

Chloride of silver	3½ oz.
Cream of tartar	7 oz.
Salt (common)	10½ oz.

Water, to form a paste.

Keep in a covered vessel away from the light. Apply with a cork or brush to the clean metallic (copper) surface, and allow the paste to dry. When rinsed in cold water the silver presents a fine frosted appearance, the brightness of which may be increased by a few seconds' immersion in dilute sulphuric acid or solution of potassium cyanide. The silvering bears the action of the wire brush and of the burnishing tool very well, and may also be "oxidized." Should a first silvering not be found sufficiently durable after scratch-brushing, a second or third coat may be applied. This silvering is not so adhering or white on pure copper as upon a gilt surface.

For the reflector of lanterns the paste is rubbed upon the reflector with a fine linen pad; then, with another rag, a thin paste of Spanish white or similar substance is spread over the reflector and left to dry. Rubbing with a fine clean linen rag restores the luster and whiteness of the silvered surface.

The paste is sometimes mixed directly with the whiting and left to dry, or until nearly dry, then rubbed down as described.

RELATIVE COST OF MOTIVE POWER.—Herr Bissinger, of Carlsrube, Germany, gives the following results as obtained in his examinations of the several motors in regard to the relative per horse power for each hour. It will be observed that the examination pertained principally to small motors. The relative cost per effective horse-power per hour is as follows:

100	horse-power steam engine	7.6
2	" "	44.3
2	" Lehmann's caloric engine.	26.5
2	" Hock's motor	40 0
2	" Otto gas engine	26.4
2	" Otto Lang gas engine	26.4
2	" Schmidt's hydraulic motor supplied with water from the city water works	95.00
2	" obtained by horses and a gin	45.00
2	" obtained by manual labor	200.00

Otto's gas motor and Lehmann's caloric engine are the cheapest of the small motors, but they are, nevertheless, four times as expensive as the 100 horse-power steam-engine.

THE following is a carefully prepared table showing the population of ten Western States for the years 1860, 1870, and 1880:

	1860.	1870.	1880.
Ohio	2,339,511	2,665,260	3,100,000
Indiana	1,350,428	1,680,637	2,056,500
Illinois	1,711,951	2,539,891	3,125,000
Missouri	1,182,012	1,721,295	2,200,000
Michigan	749,113	1,184,059	1,600,000
Wisconsin	775,881	1,054,670	1,305,000
Iowa	674,913	1,194,020	1,745,000
Minnesota	172,023	439,706	776,714
Kansas	107,206	364,399	900,000
Nebraska	28,841	122,993	452,000
Total	9,091,879	12,966,930	17,260,214

—*Bulletin.*

SOME years ago a great deal of anxiety was expressed by the most sagacious railroad managers about the probable entire loss of worn-out steel rails. They knew that iron rails when worn out could be rerolled, but it was said that Bessemer steel rails could not be rerolled in the same way, and that therefore when unfit for further use in the track they would be cast aside as valueless. Gradually however, as steel rails have been taken up they have been used by steel-manipulating works, which have themselves expanded with the steadily increasing supply of old steel rails, and now the St. Louis *Age of Steel* says: "There is considerable demand for old steel rails at $40 per ton, while the supply is not at all commensurate therewith. Old steel rails are now being used for so many purposes that the supply is not at all equal to the wants of business." —*Bulletin.*

REPORTS OF ENGINEERING SOCIETIES.

AMERICAN SOCIETY OF CIVIL ENGINEERS. The last number of the transactions is at hand, containing the following papers:

No. 203. Tensible tests of cement, and an appliance for more accurate determinations. By D. J. Whittemore.

" 204. Waterproof Coverings. By F. Collingwood.

Discussions on the above and upon papers 181 and 191 conclude the number.